THE WEATHER AND CIRCULATION OF DECEMBER 1957[1]

High Index and Abnormal Warmth

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1. CIRCULATION OF THE MONTH—FAST WESTERLY FLOW

The monthly mean circulation pattern at 700 mb. for December 1957 (fig. 1) was characterized by fast westerly flow of small amplitude, typical of high index. The monthly mean zonal index for temperate latitudes (35°–55° N.), averaged over the Western Hemisphere, was 12.7 m. p. s. and exceeded the normal for December by 1.4 m. p. s. Not only were the westerlies fast, but they were also displaced to the north. The zonal wind speed profile for this month (fig. 2) shows that the latitude of the peak speed was north of its normal position and that the maximum wind was stronger than normal. In fact, zonal wind speeds were above normal from 40° N. to 70° N. (stippled).

Typical of high index, the 700-mb. mean waves (fig. 1) had small amplitude. Rather flat troughs were observed over Japan, the eastern Pacific, eastern North America, the Mediterranean region, and western Siberia. The Siberian trough, with a departure from normal of −540 feet, was by far the strongest, and although the maximum anomaly was in the north, subnormal heights extended southward through middle latitudes into the subtropics. However, this was not true of most of the other troughs which were relatively weak and did not extend strongly into lower latitudes. The 700-mb. heights in the Asiatic coastal trough averaged above normal in most latitudes. The eastern Pacific trough was deep in the Gulf of Alaska but weak in middle latitudes, where positive anomalies extended zonally through the trough. Likewise, the North American trough was not particularly pronounced, for heights in the trough were less than 100 feet below normal.

The ridge over the western United States and the accompanying trough over the Mississippi Valley may have been a result of the influence of the earth's orography on the fast westerlies. The average position of the trough (90°–95° W. longitude) was close to the location given by Colson [2] for trough formation to the lee of the Rocky Mountains, with wind speeds of the magnitude observed.

Positive height anomalies, associated with the fast westerly flow and the small-amplitude waves at 700 mb., were zonally oriented and mainly confined to middle and low latitudes, while the negative anomalies were located in the higher latitudes (fig. 1). The positive anomalies, which resulted from extensions of the subtropical Highs northward, were most pronounced in the central Pacific and Atlantic Oceans, where the normally cyclonic flow was replaced by anticyclonic flow and small-amplitude ridges in the monthly mean. The smaller positive anomalies over western United States and the below normal heights in the Gulf of Alaska and to the east over Canada reflect the high-index regime that existed in western North America, where difluence normally occurs.

Thus far only the average wind speed for the entire Western Hemisphere and its latitudinal variations have been discussed. Usually there are important longitudinal variations of wind speed which may be highlighted by an isotach chart. This month these variations were small, especially if Eurasia is excluded. At the 700-mb. level a band of wind speeds greater than 12 m. p. s. extended continuously from China to Great Britain (fig. 3A, hatched). Within this band centers of maximum speed did occur, but they were not strong and were located near their normal wintertime positions, off the eastern coasts of the continents.

Wind speeds were above normal not only along practically the entire jet stream axis but also to the north of this axis (fig. 3B). Largest positive anomalies were over the oceans, but the super-normal winds in western United States intensified orographic effects and, therefore, had a pronounced influence on the United States weather. South of the jet axis winds were weaker than normal, with the major negative anomalies located over the oceans in the subtropics, where large zones of above normal anticyclonic shear were observed.

Most features of the December circulation were well depicted by the midtropospheric circulation, but there was an additional aspect of the circulation which was best portrayed by the 200-mb. monthly mean. Even though the upper-level (200-mb.) contour pattern appeared very similar to that at lower levels, the wind field did differ significantly (fig. 4). At 200 mb. the jet stream maximum was located over Tennessee, some 1,500 miles southwest of the 700-mb. jet maximum off Nova Scotia. The relation of this wind field to precipitation will be discussed in section 5.

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[1] See Charts I–XVII following p. 424 for analyzed climatological data for the month.

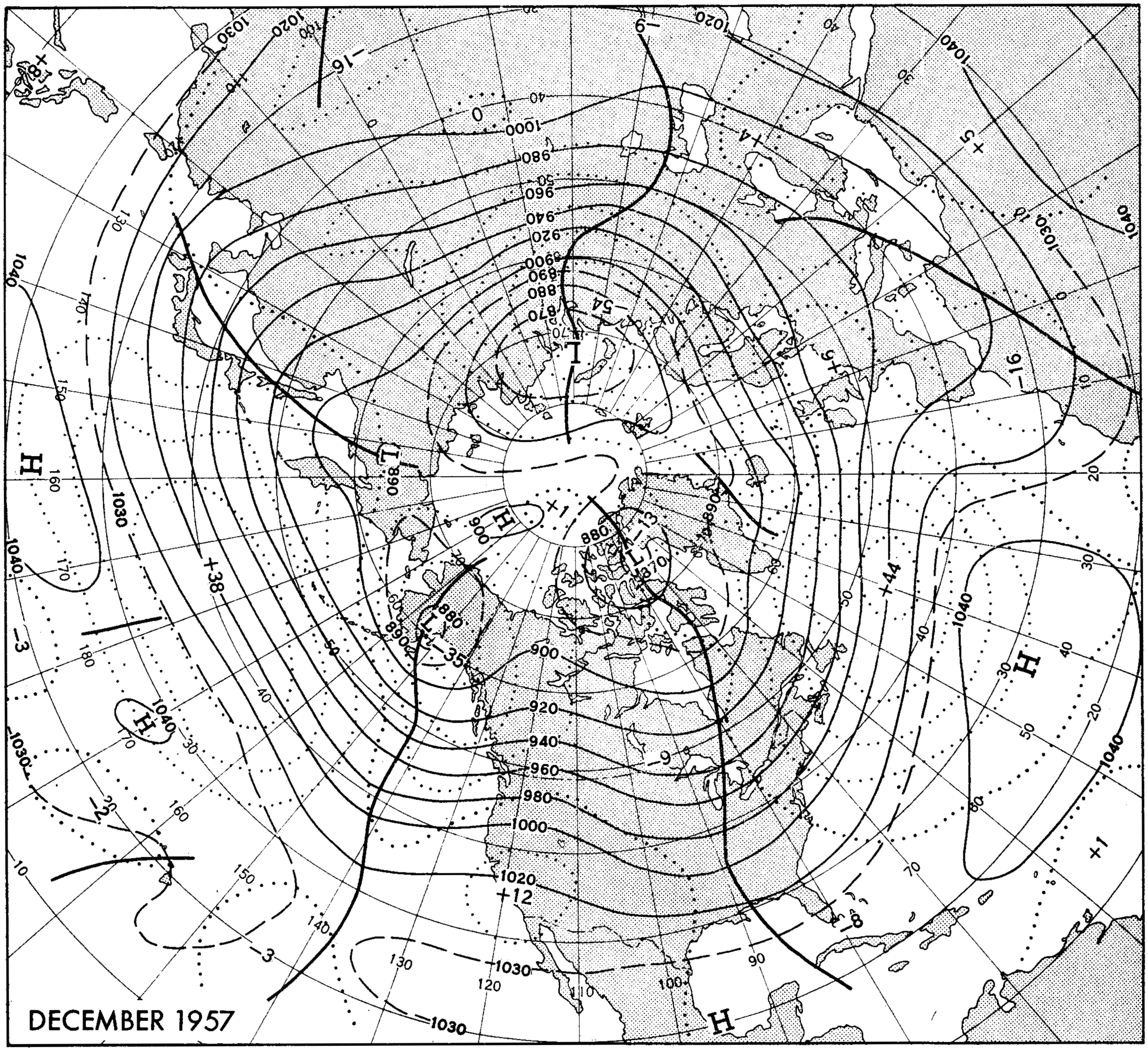


FIGURE 1.—Mean 700-mb. contours (solid) and height departures from monthly normal (dotted) (both in tens of feet) for December 1957. Fast, westerly, small-amplitude flow, typical of high index, prevailed this month.

2. CHANGE IN CIRCULATION FROM FALL TO DECEMBER

The high index circulation of December represented a marked change from the persistent low index regime that had existed throughout the fall [7]. During the fall, when blocking conditions prevailed, the temperate zone (35°–55° N.) index averaged below normal every month (table 1). (These indices and all zonal winds referred to in this section are the average for just the western half of the Northern Hemisphere.) It was not until late in November that the westerlies began a steady climb to the above normal value for December.

A quick inspection of the mean zonal wind speed profiles for November through December suggests that rather large departures from normal existed, and that these anomalies

TABLE 1.—*Monthly mean values of the zonal index at 700 mb. (in meters per second) for the area 35° N.–55 N. and 5° W.–175° E.*

	1957	Normal	Departure from normal
September	7.2	7.8	−0.6
October	7.3	9.5	−2.2
November	9.1	10.5	−1.4
December	12.7	11.3	+1.4

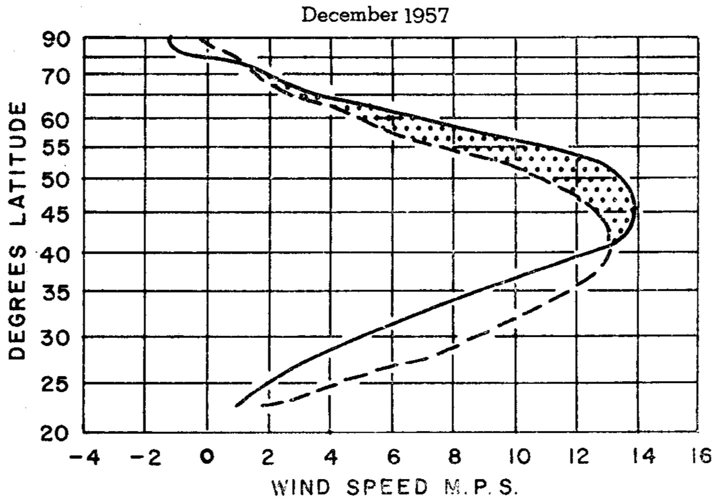


FIGURE 2.—Mean 700-mb. zonal wind speed profile in the Western Hemisphere for December 1957 (solid line) and December normal (dashed line). Westerlies were stronger than normal (stippled) and displaced to the north.

seemed to undergo systematic long-period changes. In order to examine these ideas more carefully, zonal wind speed departures from the 30-day normals were computed twice a month for 5-degree latitude bands and plotted on a time-latitude section (fig. 5). As would be expected during the period of low index, from September through November, 30-day mean zonal wind speeds were subnormal in temperate latitudes but above normal in low and high latitudes. By the 30-day period mid-November through mid-December westerlies in the middle latitudes were above normal, and they continued to strengthen to over 4 m. p. s. above normal by December. Also, the positive departures, which were located in middle latitudes, migrated northward with time. They first appeared around latitude 50° N. in mid-November and later were centered at 57° N. in December. Simultaneous with the increase in zonal wind speed anomalies at middle latitudes, negative departures from normal at low latitudes increased in magnitude, reaching a maximum of 3.5 m. p. s. in December near 30° N.

The marked differences in the wind speed anomalies from November to December resulted from abnormal changes in the actual wind speeds. In order to illustrate this, the profiles of both the normal and 1957 changes were computed. The normal change is simply the normal zonal wind speed for December at a given latitude minus the corresponding normal value for November (fig. 6, dashed). The 1957 value is the monthly mean zonal wind speed for December minus the corresponding mean value for November (fig. 6, solid). It turns out that the normal changes in wind speed from November to December are minor north of latitude 50° N., but that they are large and positive south of that latitude with a maximum change of over + 3 m. p. s. between 30° and 35° N. This year, however, the wind speeds increased in the band from 36° N. to 63° N., with a major change in excess of + 4 m. p. s. between 50° and 55° N. While this increase occurred in the higher middle latitudes, the zonal winds actually diminished in the low latitudes, contrary to the normal situation.

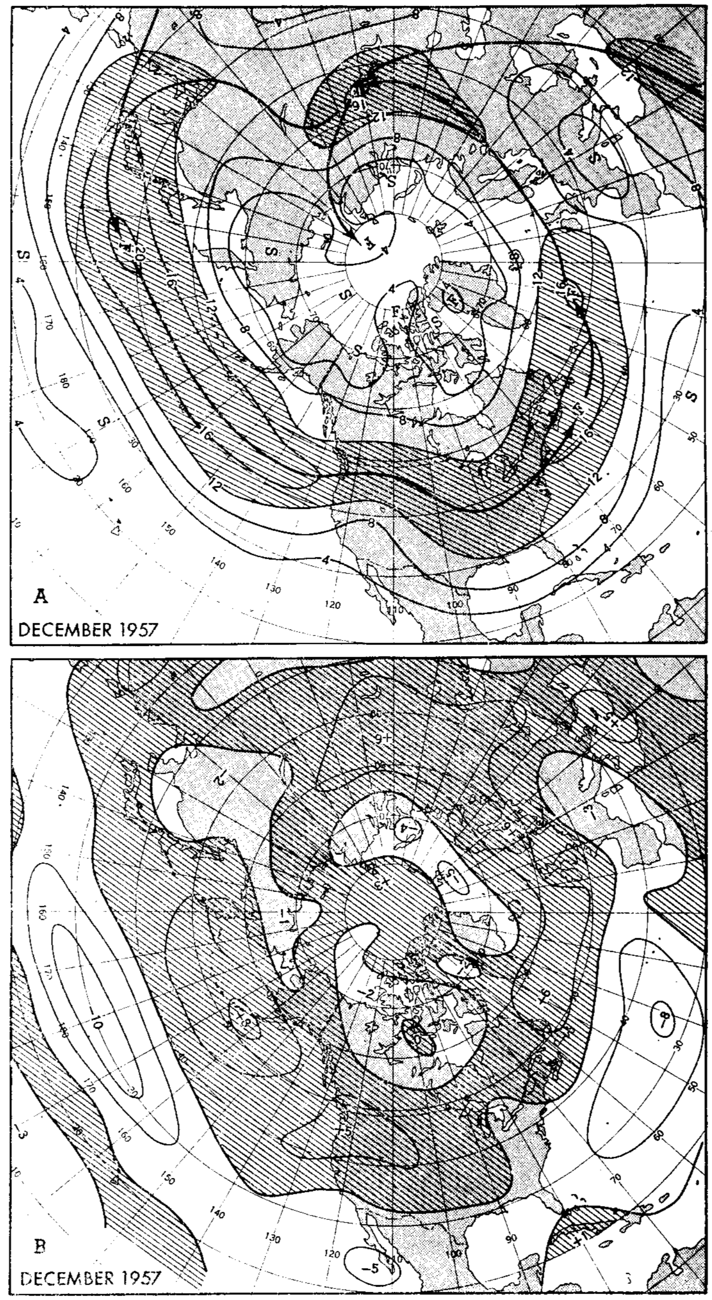


FIGURE 3.—(A) Mean 700-mb. isotachs and (B) departure from monthly normal wind speed (both in meters per second) for December 1957. Solid arrows in (A) indicate principal axes of maximum winds. Speeds greater than 12 m. p. s. have been hatched. Positive anomalies in (B) have been stippled. Faster than normal, zonally-oriented jet stream extended from China eastward to Great Britain.

While the wind field was thus changing from fall to December, there was a concomitant adjustment of the height field. The single trough in the central Pacific in November [11] was replaced by two troughs in December; one was located along the Asiatic coast and the other in the eastern Pacific (fig. 1). The trough in the United

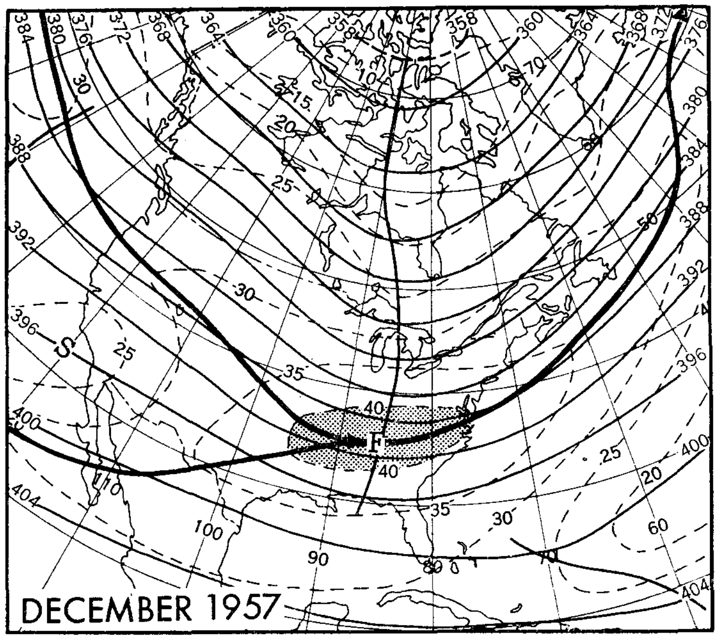


FIGURE 4.—Mean 200-mb. contours (solid in hundreds of feet) and isotachs (dashed in meters per second) for December 1957. Wind speeds greater than 40 m. p. s. are stippled. Solid arrows indicate the average position of the 200-mb. jet stream. Wind speed maximum was located over Tennessee, so that the Northeast was downstream from and north of the area of maximum winds.

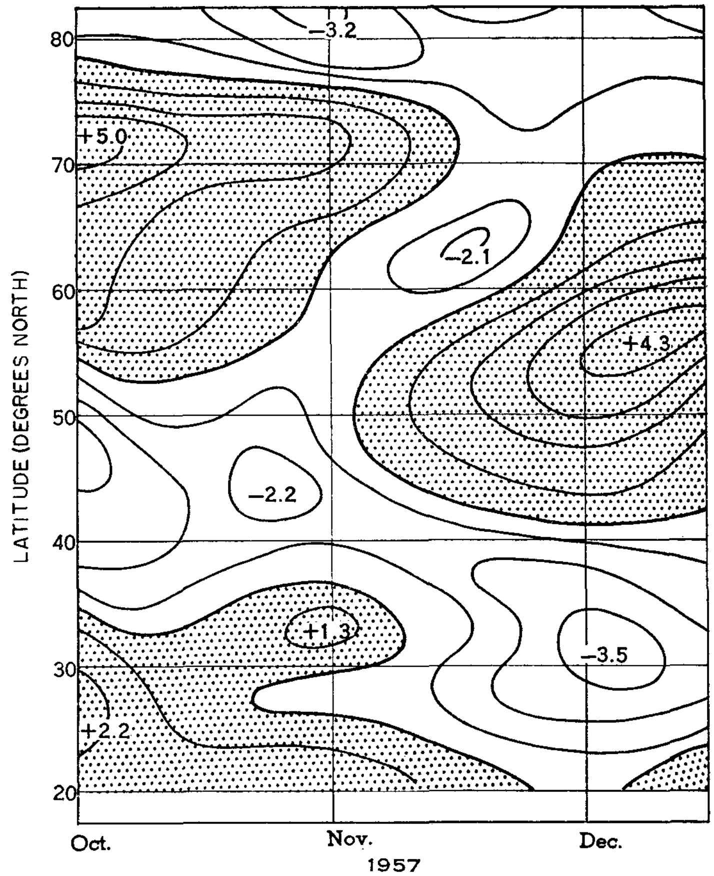


FIGURE 5.—Time variation of the departure from normal of monthly mean zonal wind speed (in meters per second), averaged over the Western Hemisphere. Isoline interval is 1 m. p. s. with anomaly centers labeled to the nearest tenth. Westerlies were stronger than normal in middle latitudes during December.

States, which extended from the Great Lakes southwestward through western Texas in November, progressed eastward in the south to the Mississippi Valley by December.

As the westerlies increased from November to December, there was an accumulation of air south of the jet stream and an evacuation in the polar regions. The principal anomalous height changes (fig. 7) were large rises over the central Pacific and Atlantic Oceans and falls extending from northern Europe and Siberia through the Arctic to the eastern Pacific. The large anomalous falls in the Gulf of Alaska and the height increases over most of the United States are the changes expected with a switch to higher index over North America.

3. TRANSITION WITHIN THE MONTH

The temperate zonal index as portrayed by the 5-day mean values (fig. 8) rose rapidly from subnormal values in November to rather high and persistently above normal values in December. The sharpest upswing occurred during the last week in November. After a period of high indices, a reduction in the westerlies occurred near mid-December. It was associated with the only large-amplitude flow pattern that occurred during the month over North America. The index fell rapidly again in the last 10 days of the month, as colder winter weather spread over the East.

The time variation of the latitudinal wind profile, again depicted by 5-day mean values (fig. 9), indicates the northward shift of the peak westerlies during the first half of December and the subsequent southward displacement, the more normal movement for this time of year. Apparently, the long-period northward shift of the westerlies terminated about mid-December. The weakening of the zonal flow is again in evidence just before mid-month, when the peak of the westerlies was farthest north and when the decrease in index took place.

Most of the 700-mb. 5-day mean charts during December (not shown) had small-amplitude waves over North America. The exception occurred in the second week, December 8–14, when a pronounced ridge in the West and sharp trough in the East were observed. The large-amplitude mean waves first appeared in the Pacific, then the meridional flow propagated rapidly downstream, modifying the waves over the United States and the Atlantic. It appeared to be a classical example of the dispersion of energy. During the rest of December the 5-day mean flow remained flat and there was a strong tendency for the same patterns to recur. Lee-troughs repeatedly formed over the Great Plains in response to the fast westerly flow and then moved eastward to the coast, but without any appreciable deepening.

4. ANTICYCLONE AND CYCLONE TRACKS

Because of the rather persistent regime of small-amplitude flow, the anticyclone and cyclone paths were

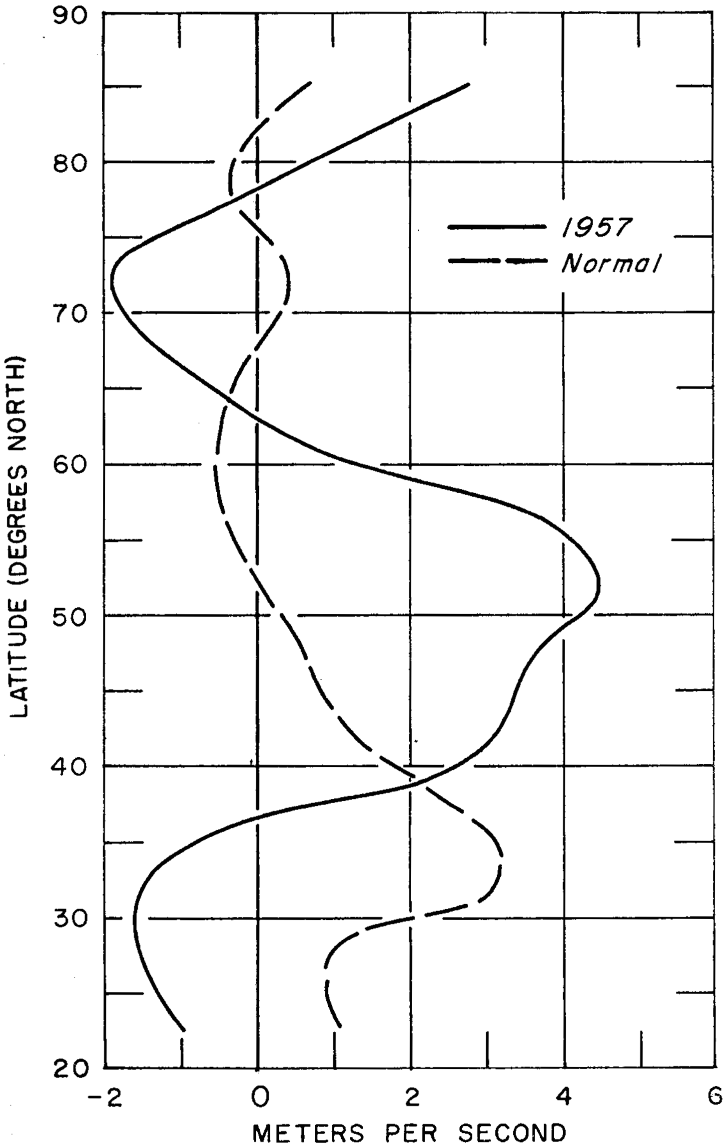


FIGURE 6.—Change in the monthly mean zonal wind speed averaged over the Western Hemisphere from November to December for 1957 (solid line) and for the normal (dashed line). Pronounced anomalous increase in westerlies occurred between 40° N. and 60° N. in December 1957.

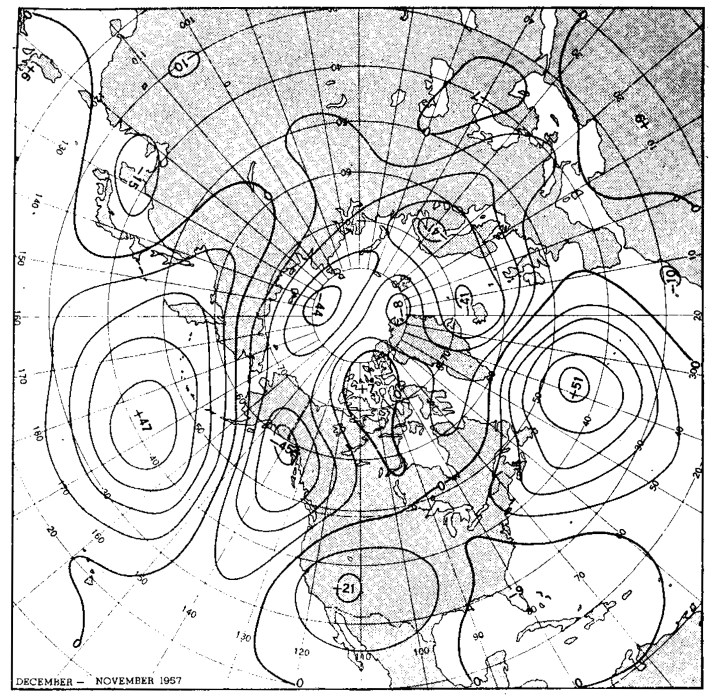


FIGURE 7.—Difference between monthly mean 700-mb. height anomaly for November and December 1957 (December minus November) in tens of feet. Isoline interval is 100 feet. Major anomalous height rises occurred in middle latitudes while falls were predominant in the higher latitudes.

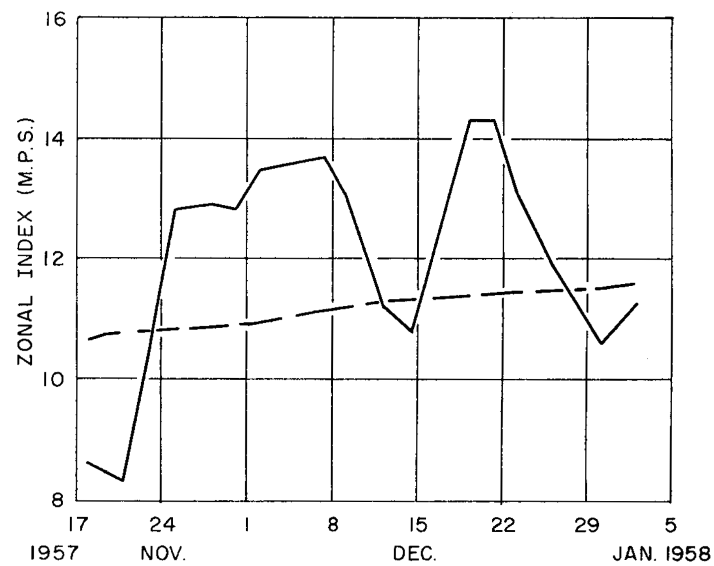


FIGURE 8.—Time variation of 700-mb. westerlies (in meters per second) over the Western Hemisphere for temperate belt (35°–55° N.). Solid line connects 5-day mean index values (plotted at middle of period and computed three times weekly) and dashed line shows variation of corresponding normal index. High index prevailed except for temporary weakening of westerlies near middle of month.

predominantly from west to east this December (Charts IX and X). There were no obvious preferred tracks of Highs over North America for they were almost uniformly distributed from the Gulf of Mexico to northern Canada. Only two polar Highs of Canadian origin had trajectories over the United States. One had only minor effects on United States weather as it grazed the northern Plains States and Great Lakes early in December, but the other produced a major polar outbreak in the second week, during the period of temporary weakening of the westerlies. This High, which formed in the Yukon on December 8, moved rapidly southward east of the Rockies to the Gulf of Mexico coast, producing a severe cold wave over the Southeast on December 12 and 13.

Most of the other Highs affecting the United States first appeared east of the Rocky Mountains as considerable anticyclogenesis occurred in the climatologically favored area over the Plains States [6]. Many of these Highs were break-offs from the Great Basin anticyclone which pre-

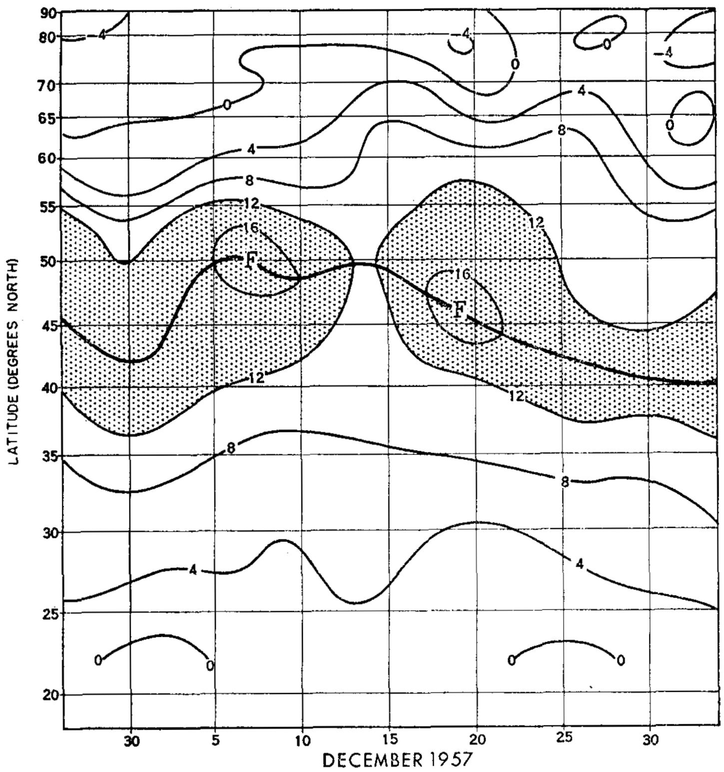


FIGURE 9.—Time-latitude section of 5-day mean zonal wind speeds (in meters per second) averaged over the Western Hemisphere at 700 mb. Five-day mean values were computed three times weekly and plotted at the middle day of the period. Values greater than 12 m. p. s. are stippled. The latitude of the axis of maximum westerlies (solid heavy line) increased from the first of December to mid-month and then decreased to the more normal location by the end of the month.

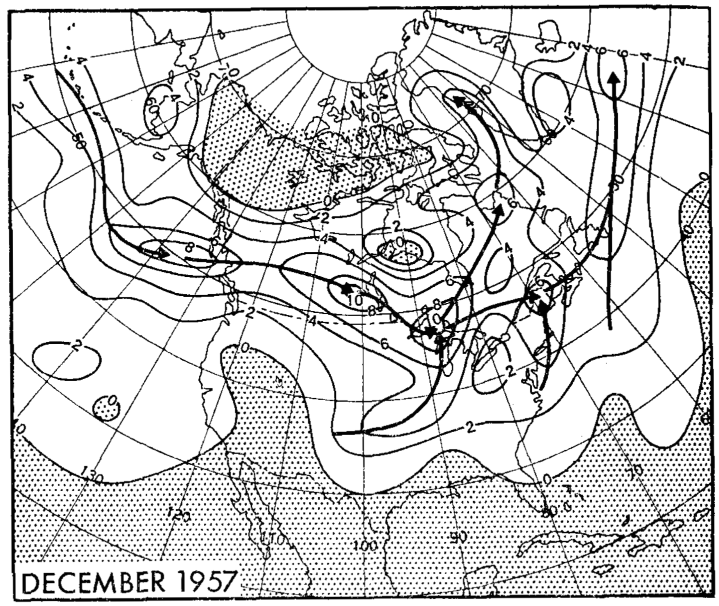


FIGURE 10.—Frequency of cyclone passages (within 5° latitude squares adjusted to 45° N. [6]) during December 1957. Zones of most frequent cyclone passage are indicated by solid arrows. Alberta type Lows typical of high index were prevalent. Note high frequency of cyclones over the relatively warm Great Lakes.

vailed as a typical feature of the high-index regime (Chart XI).

During this month cyclogenesis was favored over the Plains States in the lee of the western massif. Several "Colorado" or "Texas" Lows formed and moved northeastward through the Great Lakes (fig. 10 and Chart X) along the climatologically preferred course [6]. Cyclones from the Pacific also penetrated North America. Because the upper-level flow was strong and north of its normal position, the northern principal storm track through southern Canada [6] became the preferred path, and numerous "Alberta" Lows crossed the mountains and moved southeastward into the Great Lakes region. This preferred path, as well as many other features of this month, closely resembled December 1953, another high index month [12].

5. WEATHER OF THE UNITED STATES

TEMPERATURE—ABNORMAL WARMTH

December was an abnormally warm month, with its weather in many northern areas more typical of fall than winter. During the 3-month extended period of low index this fall, temperatures over most of the country averaged below normal [1, 4, 7, 10 No. 49, 11]. As December approached and the westerlies increased, warm, maritime Pacific airmasses invaded the United States. Foehn action further warmed the Pacific airmasses as they flowed down the eastern slopes of the western mountain ranges. This mild air was spread eastward over the country by the strong zonal flow, so that most areas experienced above normal temperatures each week. Largest positive anomalies prevailed in the Northern Plains and Rocky Mountain States under the jet stream where the foehn warming was most pronounced. 70 m. p. h. chinook winds were reported on the 7th and 10th at Rapid City, S. Dak., and this warm air reached as far east as Sioux City, Iowa, where 70 m. p. h. gusts and 63° temperatures were reported on the 10th. Several stations, in the West including Havre and Glasgow, Mont., Sheridan, Wyo., Norfolk, Nebr., Raton, N. Mex., and Los Angeles and San Diego, Calif., reported the warmest December on record.

The areal extent of mild weather generally increased throughout December. During the third week only the southern half of Florida reported colder than normal weather (fig. 11), and in the fourth week only two small areas of subnormal temperatures in the far Southwest were observed. Further evidence of December's warmth was the fact that navigation did not end at Green Bay, Wis., until December 30, second latest date on record.

It has already been mentioned that the one major cold wave of December occurred during the second week when a polar airmass moved rapidly south-southeastward from western Canada to the Gulf. The maximum 63° F. temperature at Sioux City, Iowa, on the 10th, previously referred to, dropped to a minimum of 8° F. later that

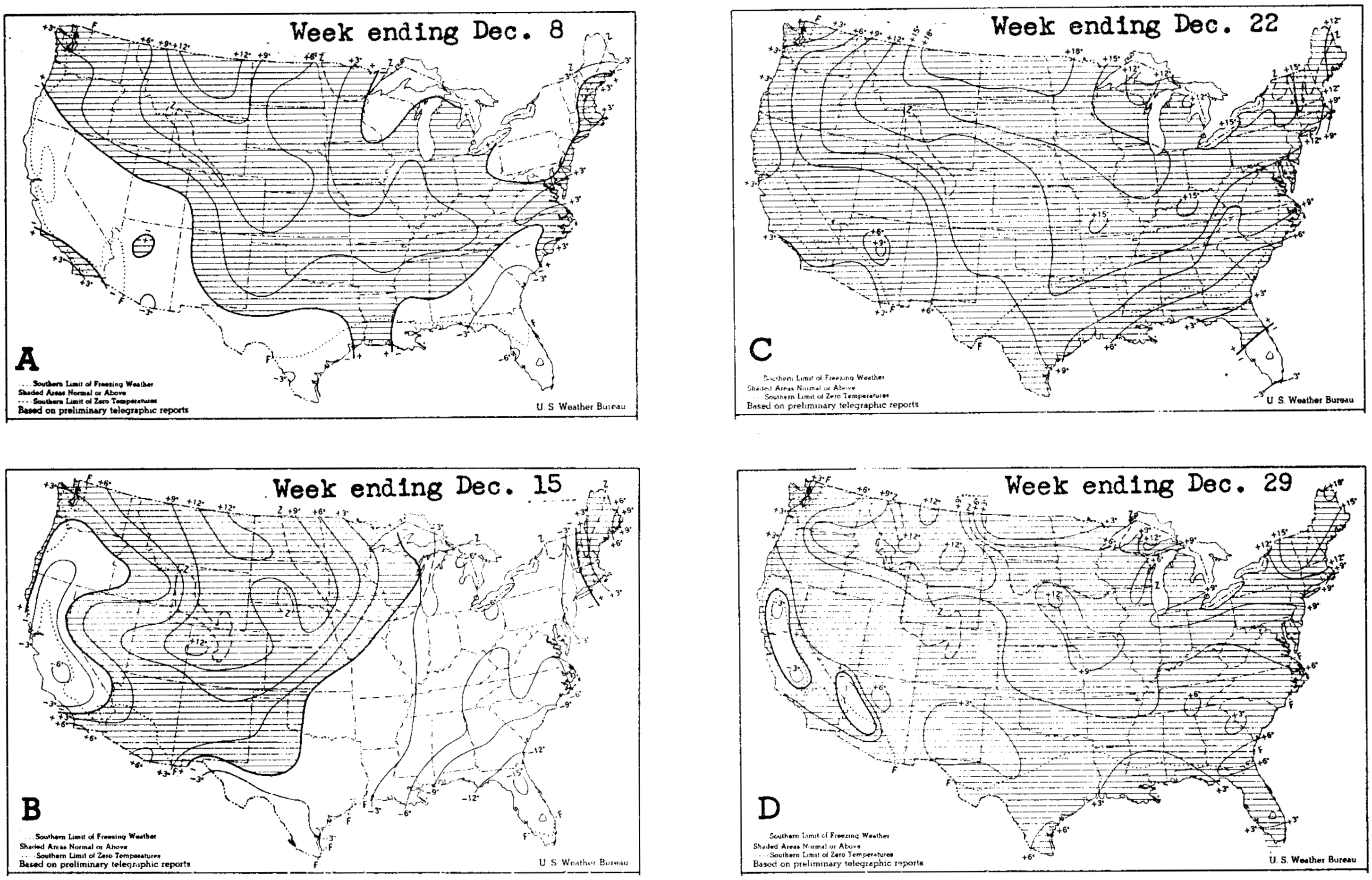


FIGURE 11.—Departure of average surface temperature from normal (°F.) for weeks in December 1957 (from [10]). Abnormally warm weather prevailed, especially in the Great Plains. One cold wave produced a hard freeze in the Southeast during the second week.

day as the cold air moved southward. This cold airmass settled over the Southeast, and weekly temperatures averaged 15° F. below normal in Florida. Freezing temperatures were reported from all areas east of the Rocky Mountains except for extreme southern Florida and Texas. In Florida, cold temperatures on the 12th and 13th approached those of the historic freezes of December 1934 and January 1940. The worst crop damage was confined to Florida and southern Texas. Damage to citrus groves is reported to be large, but the total extent will not be determinable for some time.

PRECIPITATION—TYPICAL OF HIGH INDEX

The December precipitation pattern (Chart II) was well related to the 700-mb. mean flow (fig. 1). Precipitation was generally widespread west of the Continental Divide but particularly intense along the Pacific coastal slopes, where the rainfall was enhanced by the orographic component of the strong westerlies. Up to 14 inches of precipitation fell in the extreme Northwest. Except for Minnesota, most areas of the Central and East Coast States, which were located under or east of the mean trough at 700 mb., received 2 or more inches of precipitation, but the above normal amounts were confined to the Northeast. Indianapolis, Ind., and Worcester, Mass., reported the wettest December on record.

In the lower troposphere the northeastern United States was under the domination of the large positive 700-mb. height anomaly which was centered in the Atlantic (fig. 1). Anomalous wind components [5] associated with this large departure from normal had a southeasterly trajectory from the Atlantic over the northeastern United States, producing a prevailingly maritime regime. At the 200-mb. level wind speeds over the Northeast decreased downstream (fig. 4), but at the 700-mb. level they increased downstream (fig. 3A). This particular configuration may be related to the precipitation, provided it is assumed that the mean isotach maximum indicates the preferred seat of the daily jet maxima. Since the Northeast was located north of the jet stream axis at 200 mb. and downstream from the jet maximum, it was in exactly the favorable area for upper-level divergence and precipitation according to Riehl [8]. The opposite variation of the wind speed in the lower troposphere, below the level of non-divergence, as indicated by the 700-mb. flow, favors convergence and precipitation. A similar relation was noted over the Great Plains in May 1957 [3].

In the lee of the Divide, over the Plain States, the rain shadow was pronounced. Raton, N. Mex., reported the driest December on record, and other small areas received no measurable precipitation during the month.

Numerous tornadoes were reported on the 18th and

19th in Illinois and nearby areas of neighboring States. This was unseasonably far north for tornado occurrence, but this shift was compatible with the spring-like, northward displacement of the westerlies and the temperature pattern of this December.

6. HURRICANE NINA

In view of the rare occurrence of hurricanes in the eastern Pacific at this season, a brief discussion of hurricane Nina is warranted. Nina was the second hurricane to threaten the territory of Hawaii in recent times [9]. A storm with winds up to 50 knots was first detected on November 29 near Palmyra Island (about 1,000 miles southeast of Honolulu). By December 1 Nina had developed into hurricane intensity. Winds generally of 70 knots with gusts to 90 knots persisted near the center during its northward movement to the vicinity of Kauai Island. On December 4, hurricane Nina reached its highest intensity with sustained wind speeds of 90 knots. Its force decreased thereafter as it moved westward, and by December 7, when the last advisory was issued, the winds had diminished to 30 knots, as it dissipated south of Midway.

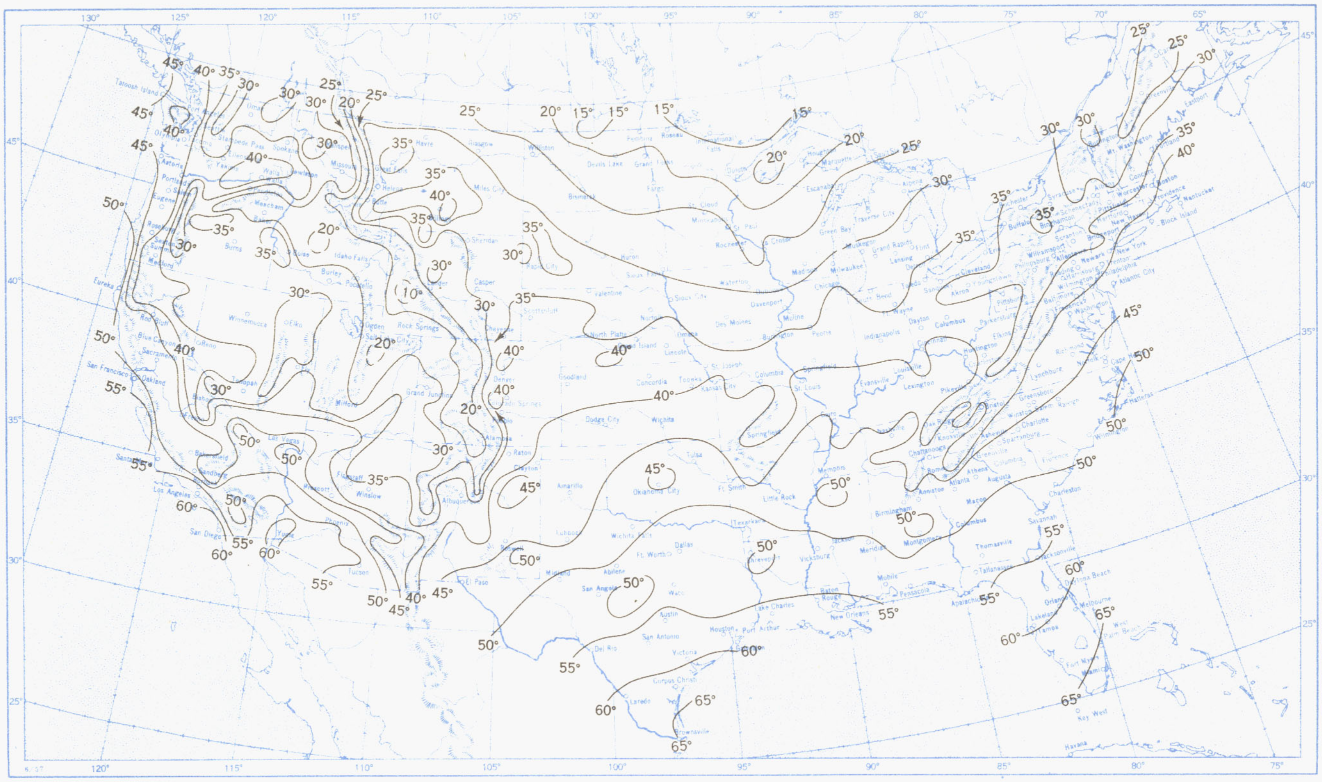
Strong winds and high waves did some damage to the Hawaiian Islands on November 30. Most of the unusually high winds were observed on the lee slopes, with maximum sustained speeds about 35 knots. At Honolulu Airport gusts of 71 knots set an all-time record on the night of November 30, when the eye of hurricane Nina was located about 300 miles south-southwest of Honolulu.

Heavy rainfall of 20.42 inches occurred in a 14-hour period between about 8:00 a. m. and 10:50 p. m., December 1, at Wainiha on Kauai. Roads were washed out by floods from heavy rains, and homes were damaged by high waves on the coast of southern Kauai.

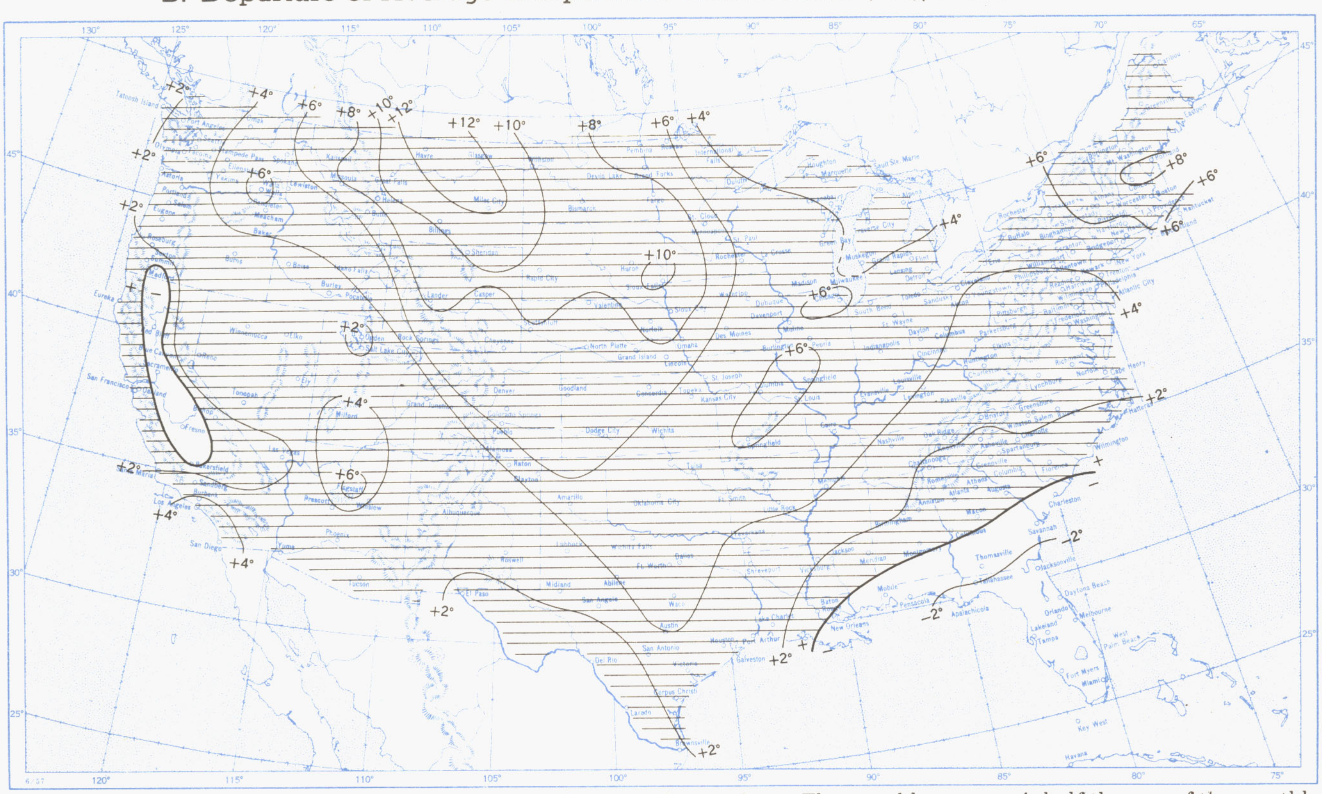
REFERENCES

1. E. M. Ballenzweig, "The Weather and Circulation of September 1957—Including a Discussion of Tropical Storm Activity, *Monthly Weather Review*, vol. 85, No. 9, September 1957, pp. 315–325.
2. D. Colson, "Air Flow Over a Mountain Barrier," *Transactions of the American Geophysical Union*, vol. 30, No. 6, Dec. 1949, pp. 818–830.
3. C. R. Dunn, "The Weather and Circulation of May 1957—A Month with Severe Floods and Devastating Tornadoes in the Southern Plains of the United States," *Monthly Weather Review*, vol. 85, No. 5, May 1957, pp. 175–182.
4. H. M. Frazier, "The Weather and Circulation of October 1957—A Month with a Record Low Zonal Index for October in the Western Hemisphere," *Monthly Weather Review*, vol. 85, No. 10, Oct. 1957, pp. 341–349.
5. H. F. Hawkins, Jr., "The Weather and Circulation of October 1956—Including a Discussion of the Relationship of Mean 700-mb. Height Anomalies to Sea Level Flow," *Monthly Weather Review*, vol. 84, No. 10, Oct. 1956, pp. 363–370.
6. W. H. Klein, "Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere," *Research Paper* No. 40, U. S. Weather Bureau, Washington, D. C., Sept. 1956, 60 pp.
7. W. H. Klein, "The Circulation and Weather of 1957," *Weatherwise*, vol. 11, No. 1, Feb. 1958.
8. H. Riehl et al., "Forecasting in Middle Latitudes," *Meteorological Monographs*, vol. 1, No. 5, American Meteorological Society, June 1952 (see pp. 33–37).
9. U. S. Weather Bureau, *Hurricane Nina, A Preliminary Report and the Advisories Issued by the Weather Bureau at Honolulu, T. H.*, Washington, D. C., December 11, 1957, 8 pp.
10. U. S. Weather Bureau, *Weekly Weather and Crop Bulletin, National Summary*, vol. XLIV, Nos. 49–52, December 9, 16, 23, 30, 1957.
11. C. M. Woffinden, "The Weather and Circulation of November 1957—A Stormy Month with a Deep Trough over Central North America," *Monthly Weather Review*, vol. 85, No. 11, Nov. 1957, pp. 367–372.
12. J. S. Winston, "The Weather and Circulation of December 1953—A Month of Fast Westerly Flow," *Monthly Weather Review*, vol. 81, No. 12, Dec. 1953, pp. 392–396.

Chart I. A. Average Temperature (°F.) at Surface, December 1957.



B. Departure of Average Temperature from Normal (°F.), December 1957.



A. Based on reports from over 900 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.

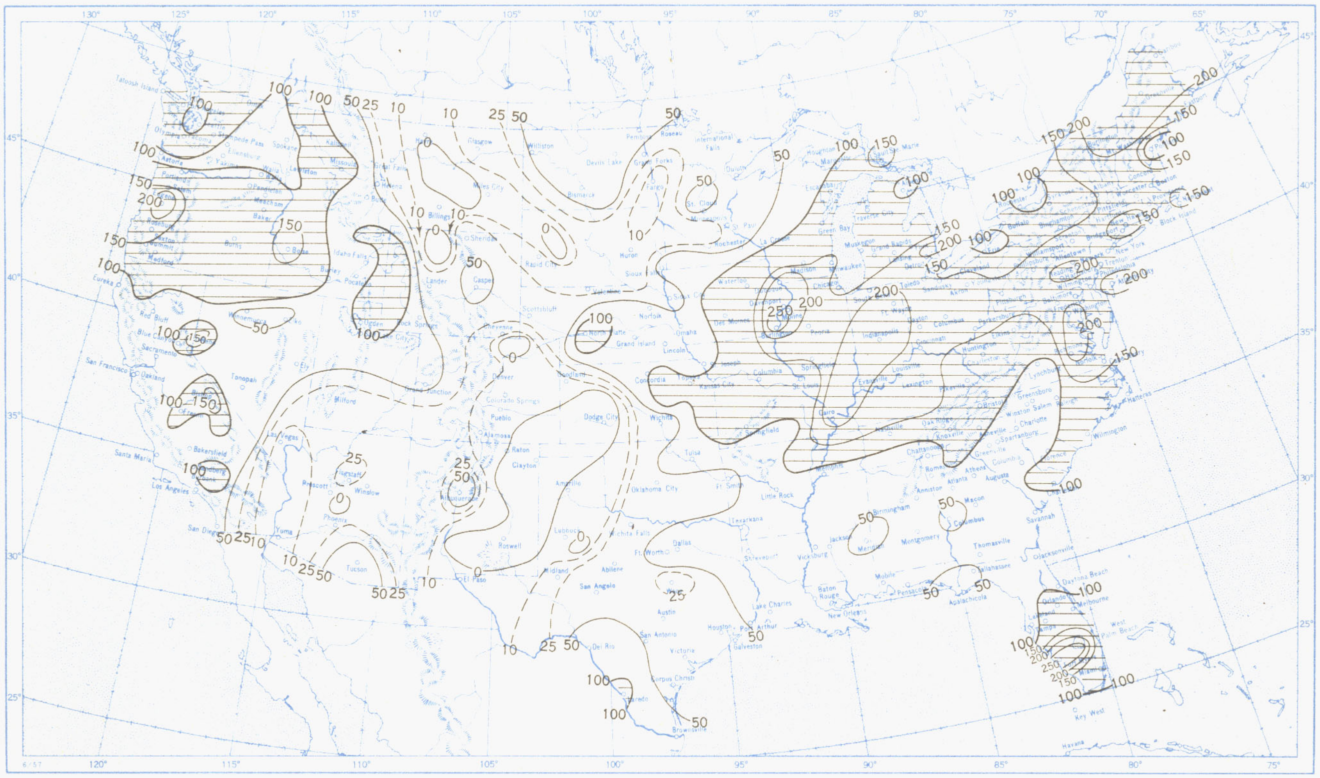
B. Departures from normal are based on the 30-yr. normals (1921-50) for Weather Bureau stations and on means of 25 years or more (mostly 1931-55) for cooperative stations.

Chart II. Total Precipitation (Inches), December 1957.

Based on daily precipitation records at about 800 Weather Bureau and cooperative stations.

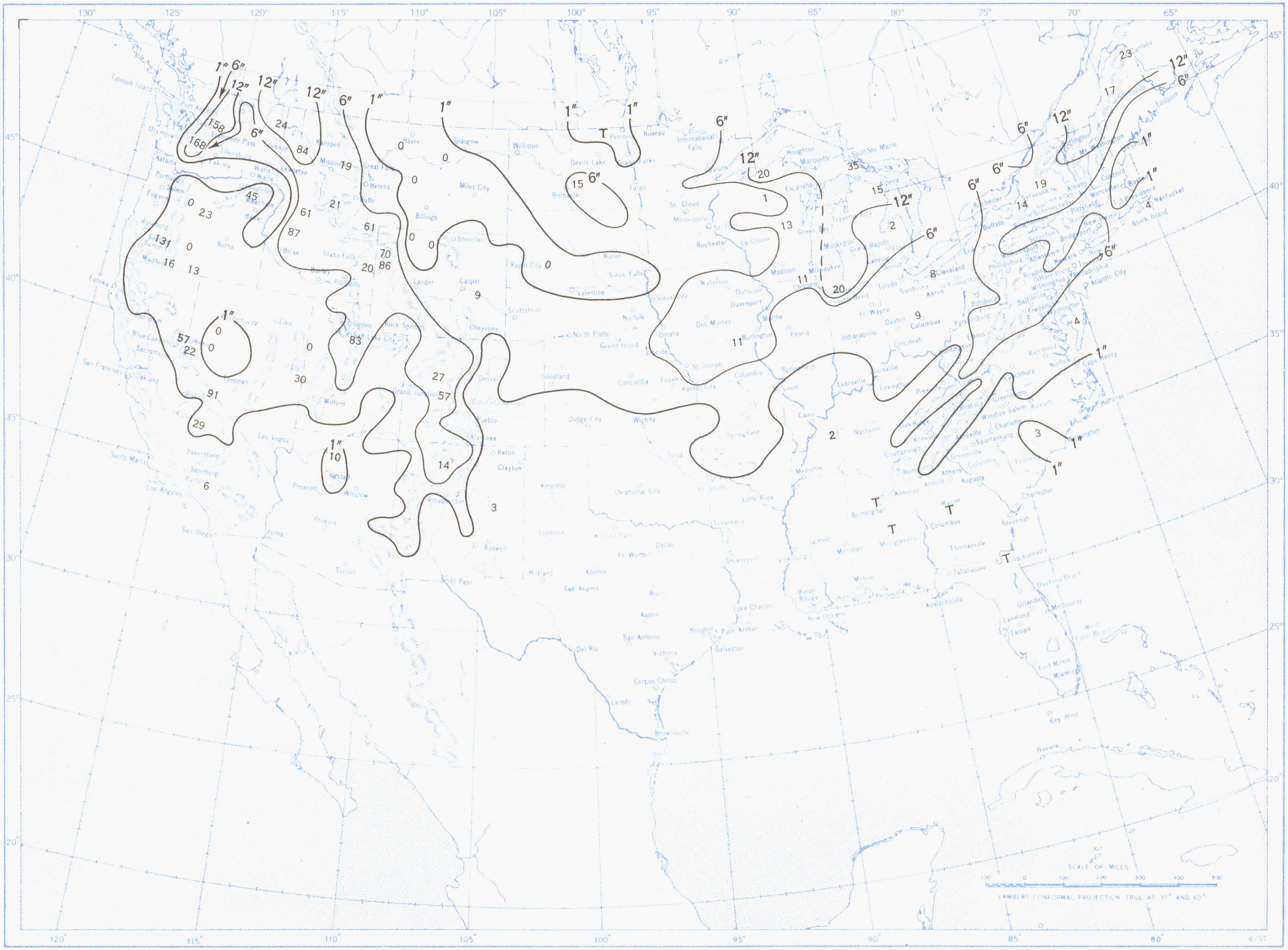
Chart III. A. Departure of Precipitation from Normal (Inches), December 1957.

B. Percentage of Normal Precipitation, December 1957.



Normal monthly precipitation amounts are computed from the records for 1921-50 for Weather Bureau stations and from records of 25 years or more (mostly 1931-55) for cooperative stations.

Chart IV. Total Snowfall (Inches), December 1957.



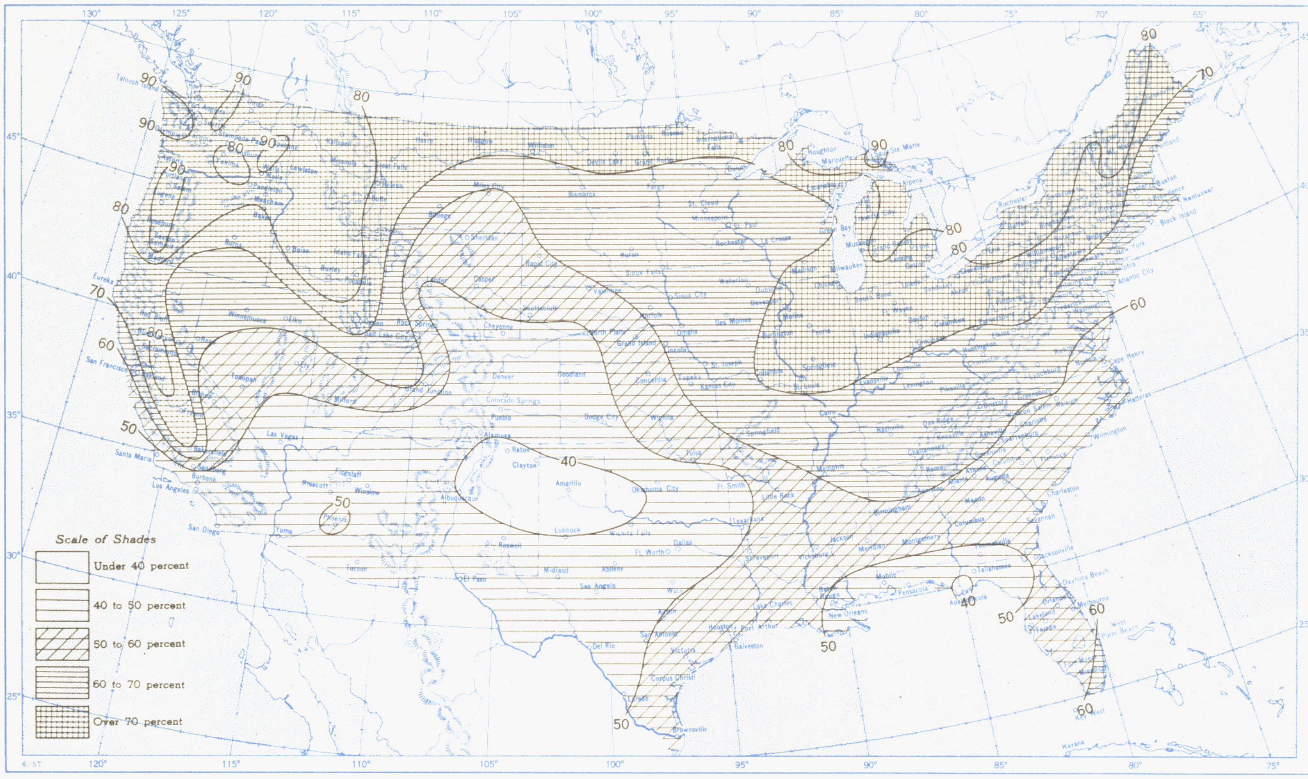
This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, December 1957.

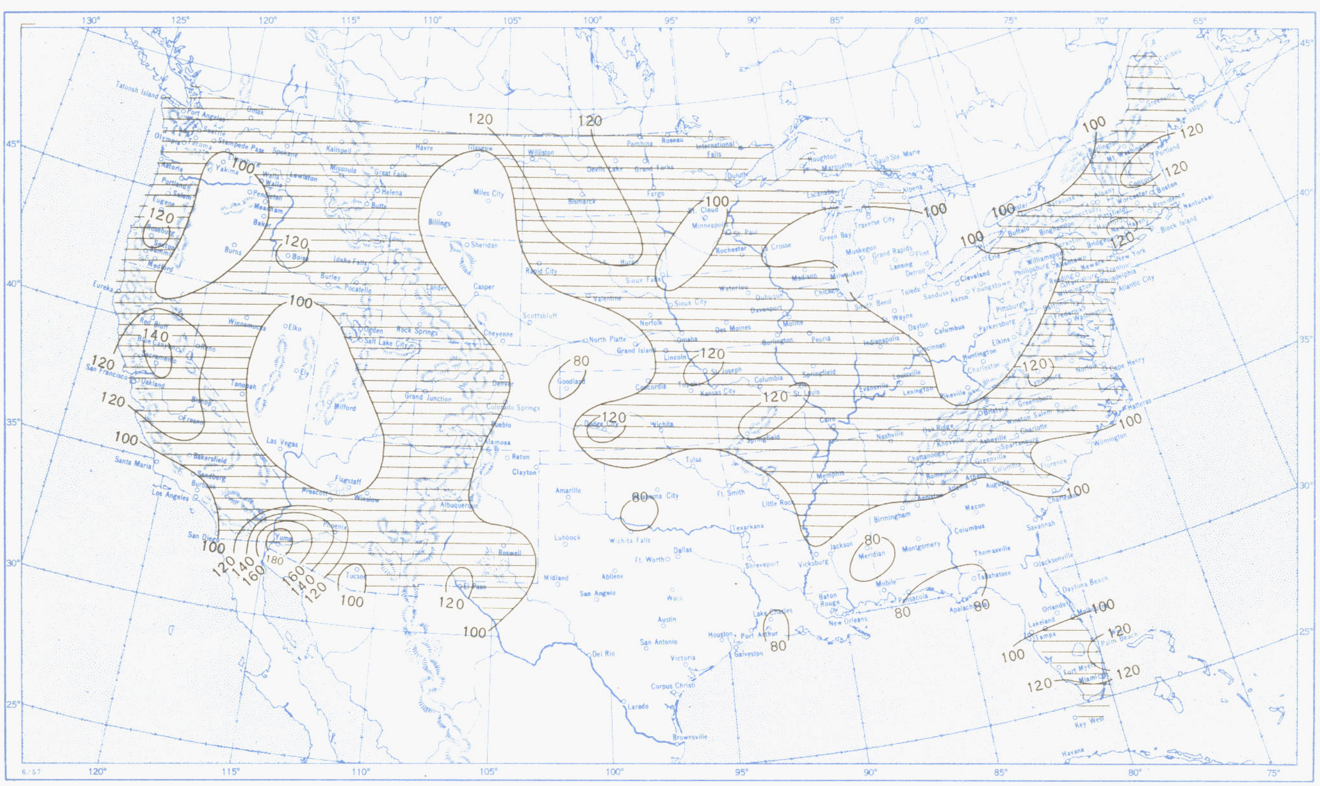
B. Depth of Snow on Ground (Inches), 7:00 a. m. E. S. T., December 30, 1957.

A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record.
B. Shows depth currently on ground at 7:00 a. m. E. S. T., of the Monday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, December 1957.

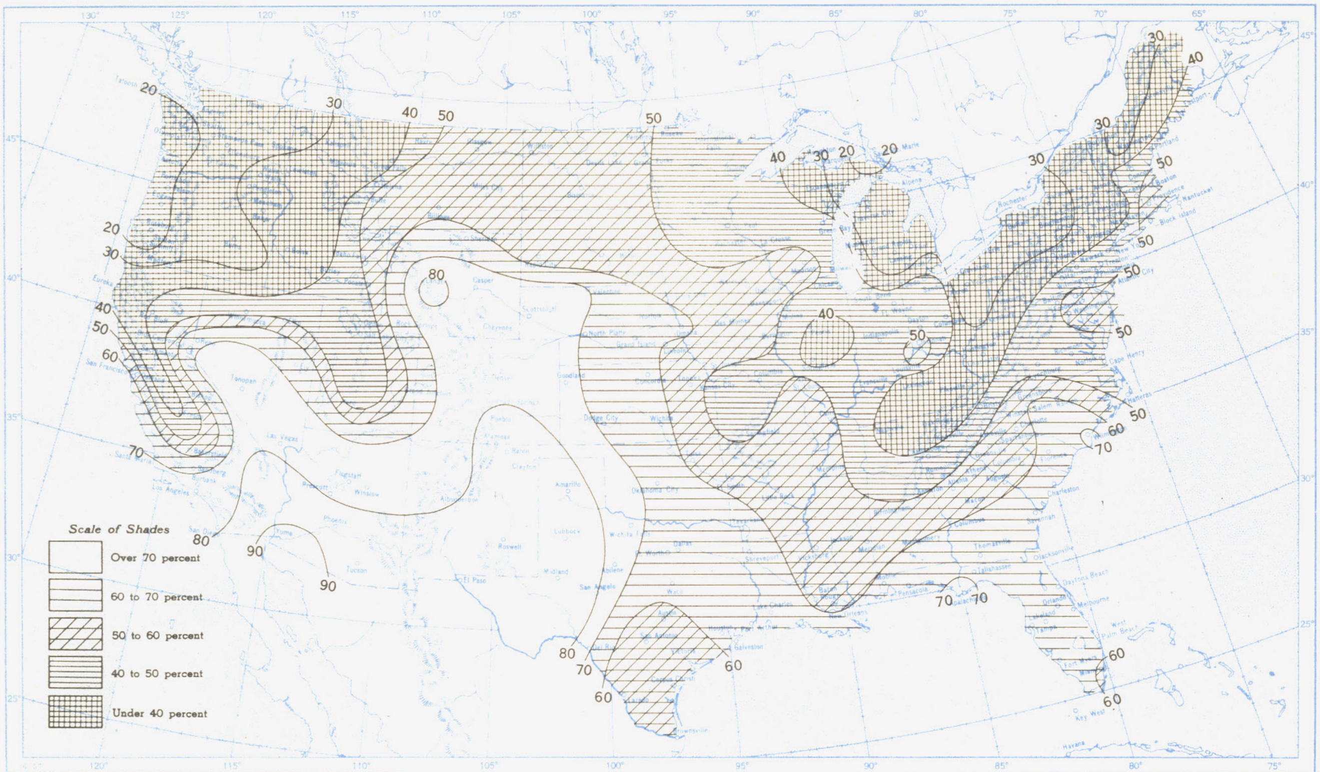


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, December 1957.

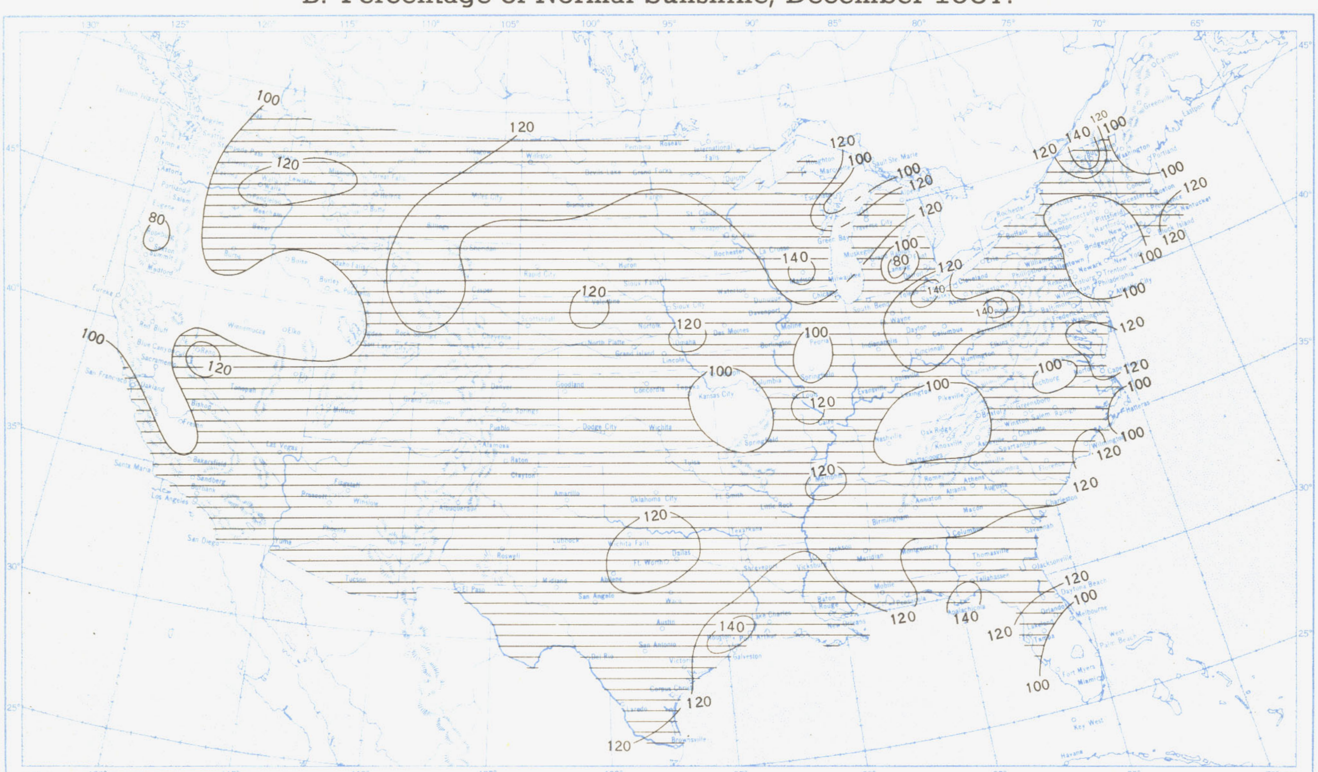


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, December 1957.



B. Percentage of Normal Sunshine, December 1957.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, December 1957. Inset: Percentage of Mean Daily Solar Radiation, December 1957. (Mean based on period 1951-55.)

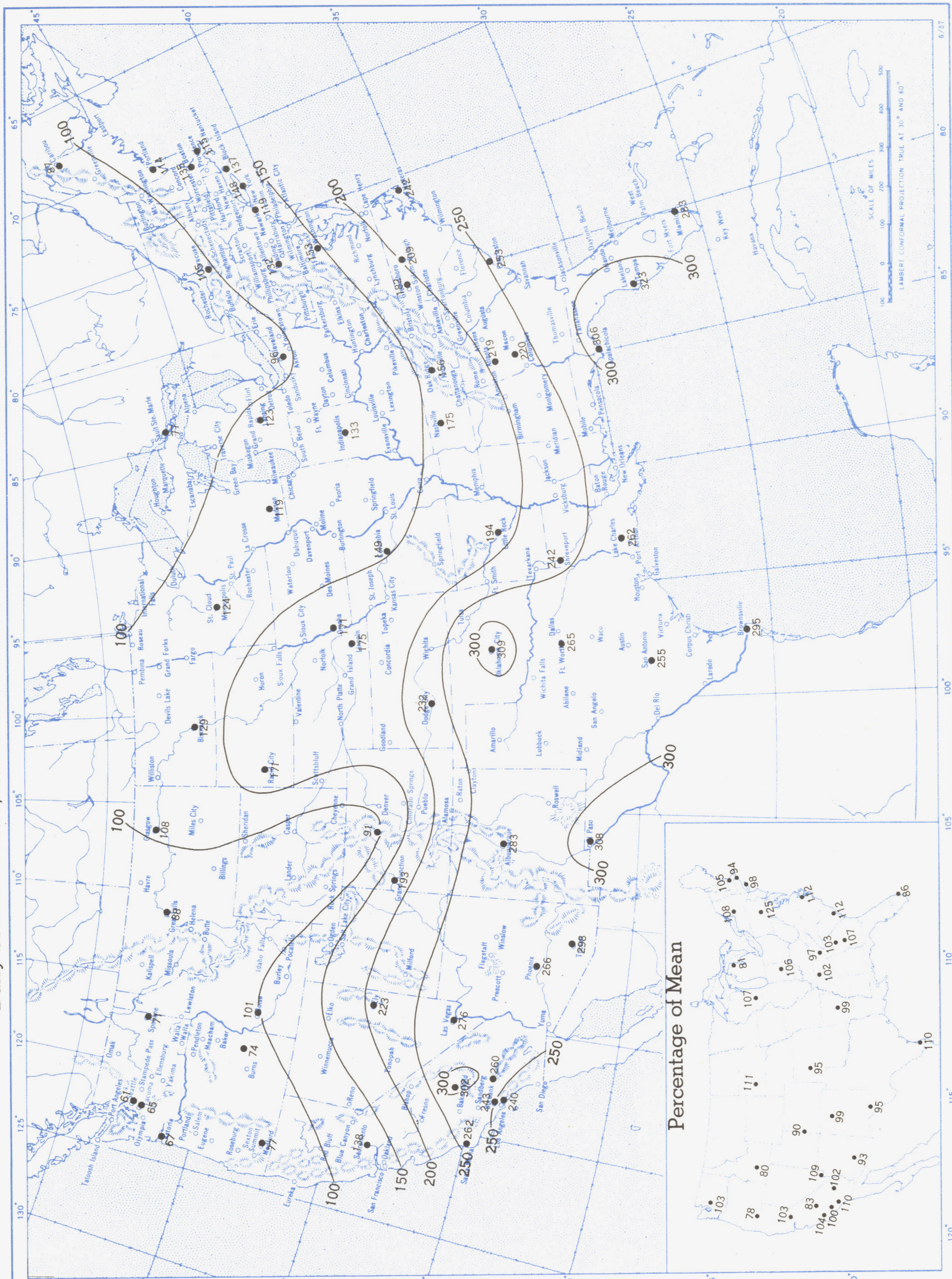
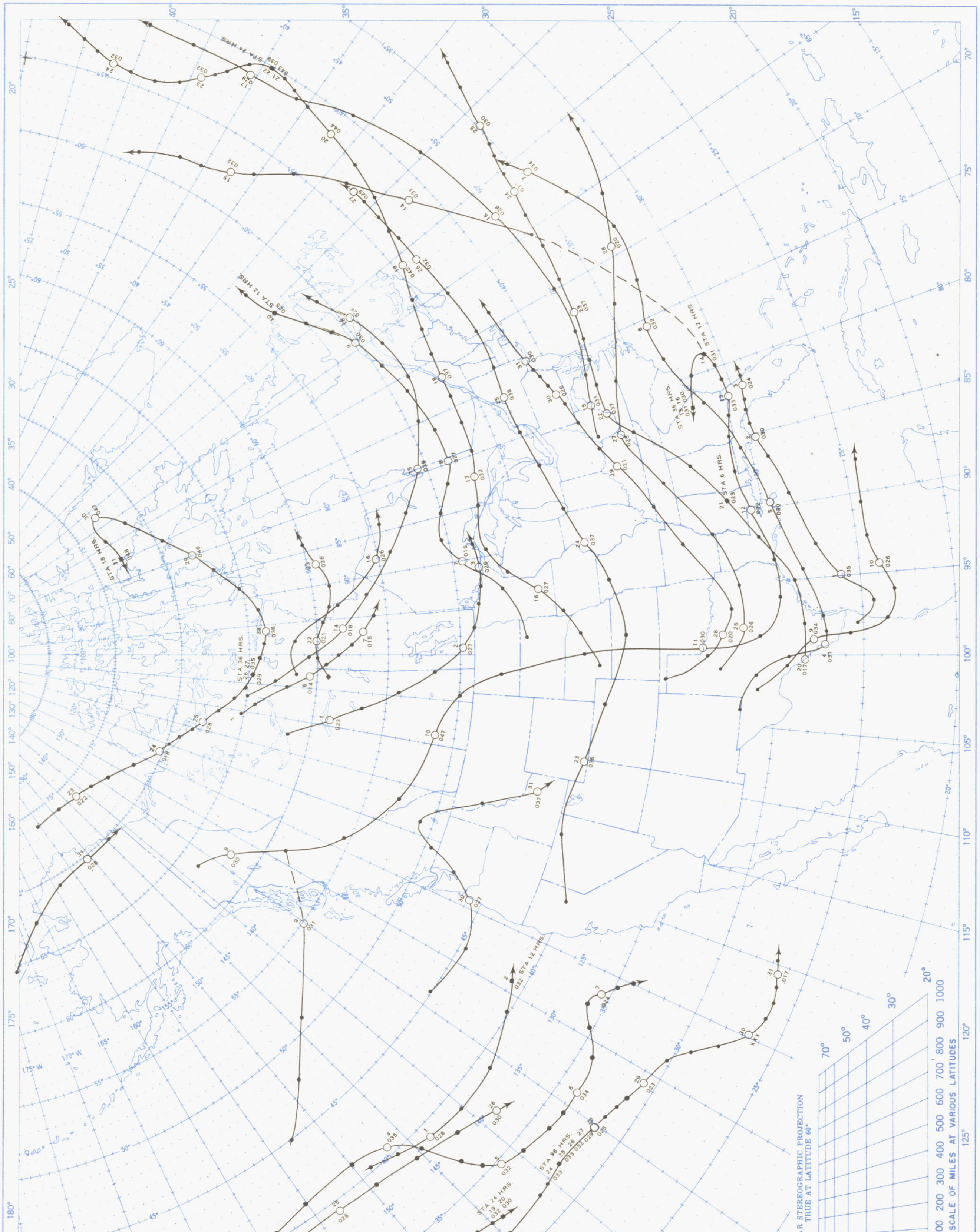


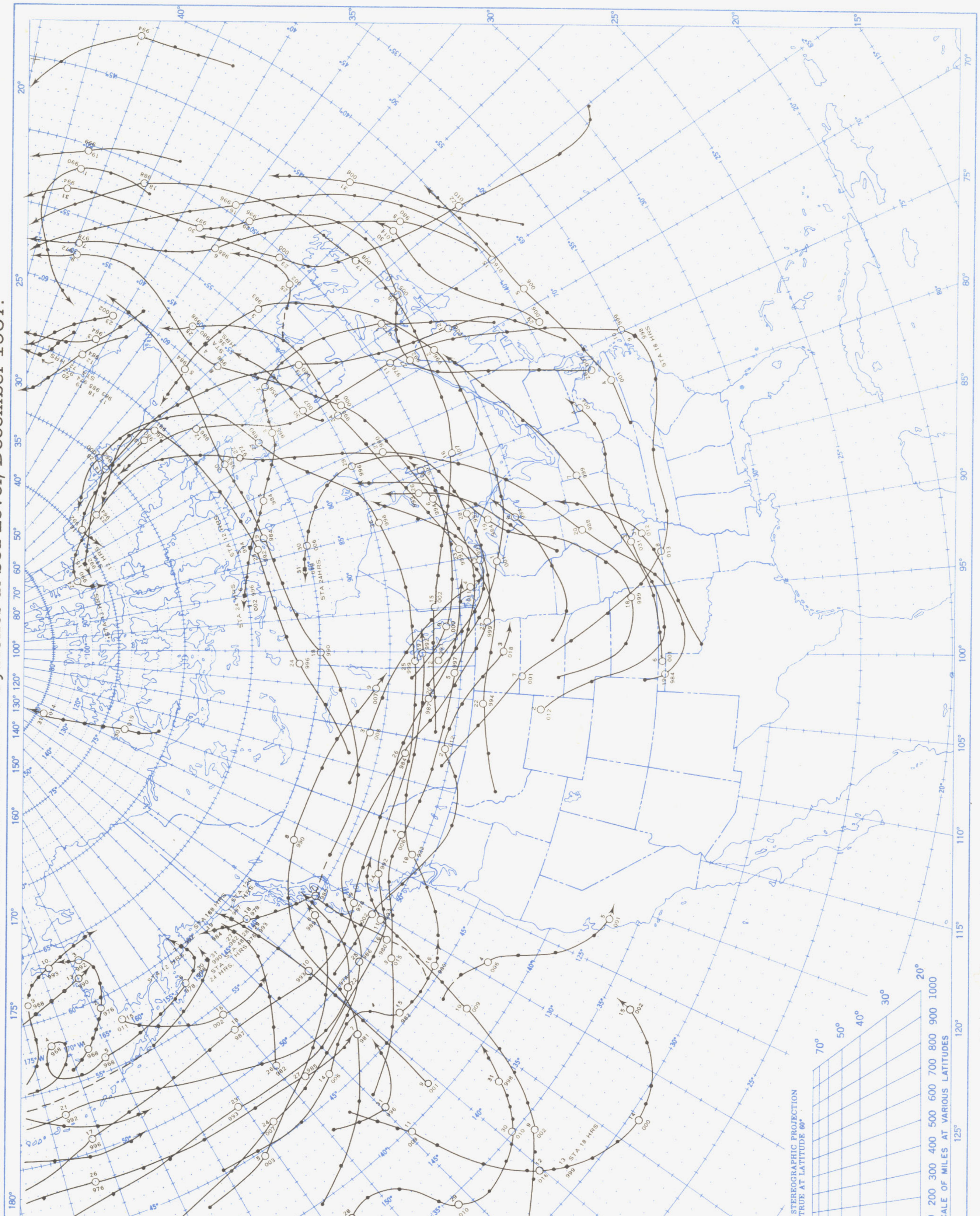
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm.$^{-2}$). Basic data for isolines are shown on chart. Further estimates are obtained from supplementary data for which limits of accuracy are wider than for those data shown.
The inset shows the percentage of the mean based on the period 1951-55.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, December 1957.



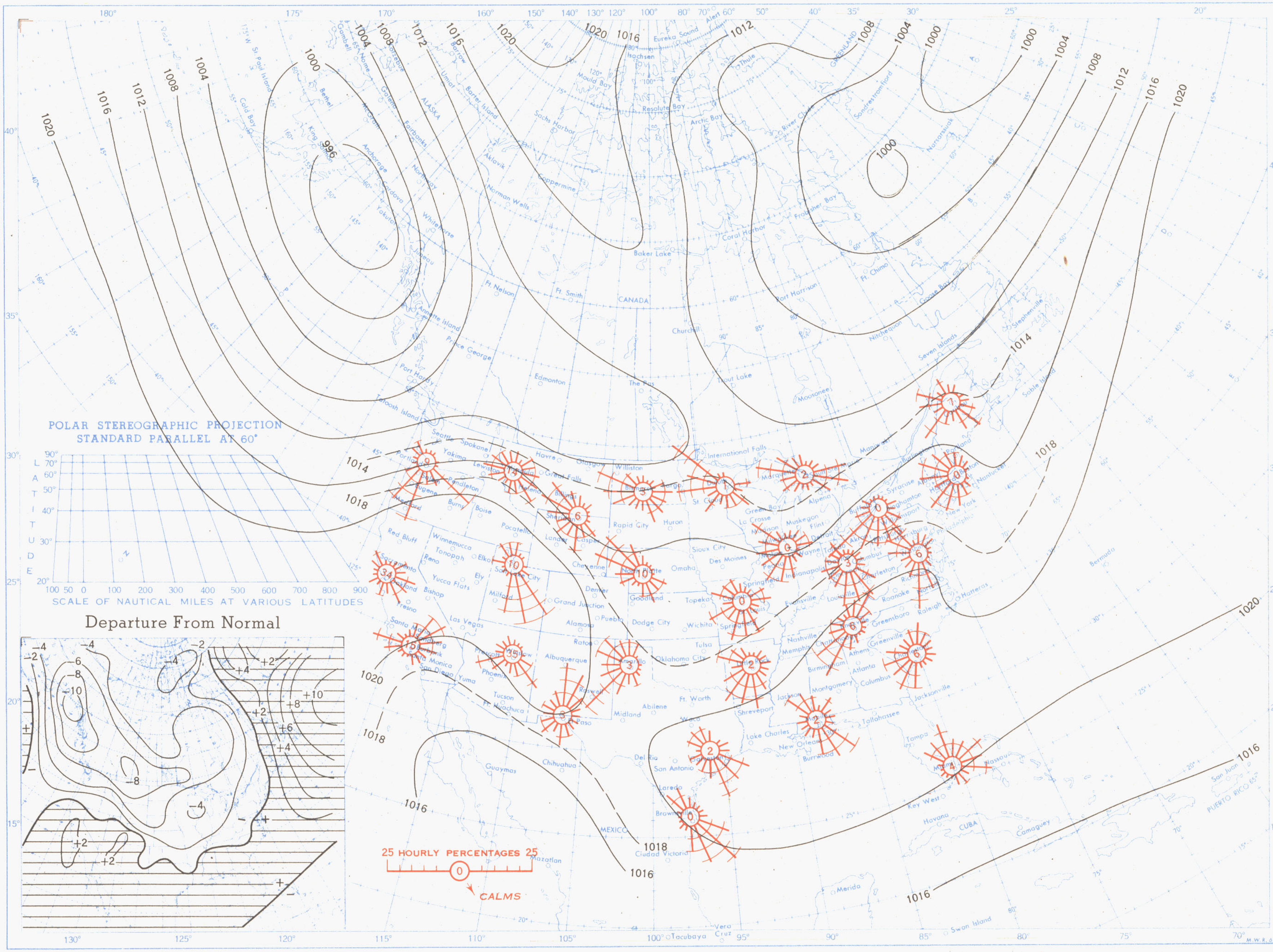
Circle indicates position of center at 7:00 a.m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, December 1957.



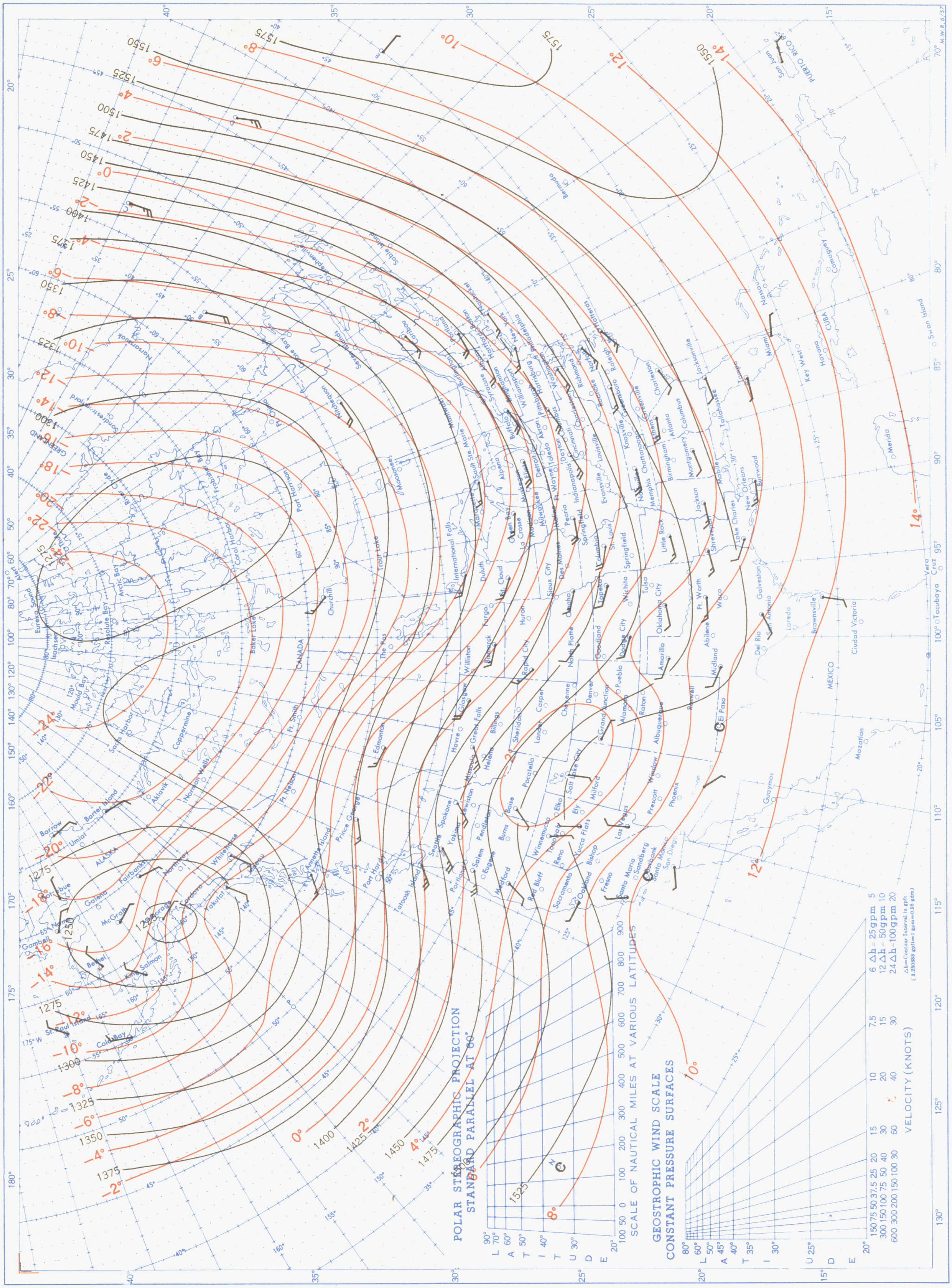
Circle indicates position of center at 7:00 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, December 1957. Inset: Departure of Average Pressure (mb.) from Normal, December 1957.



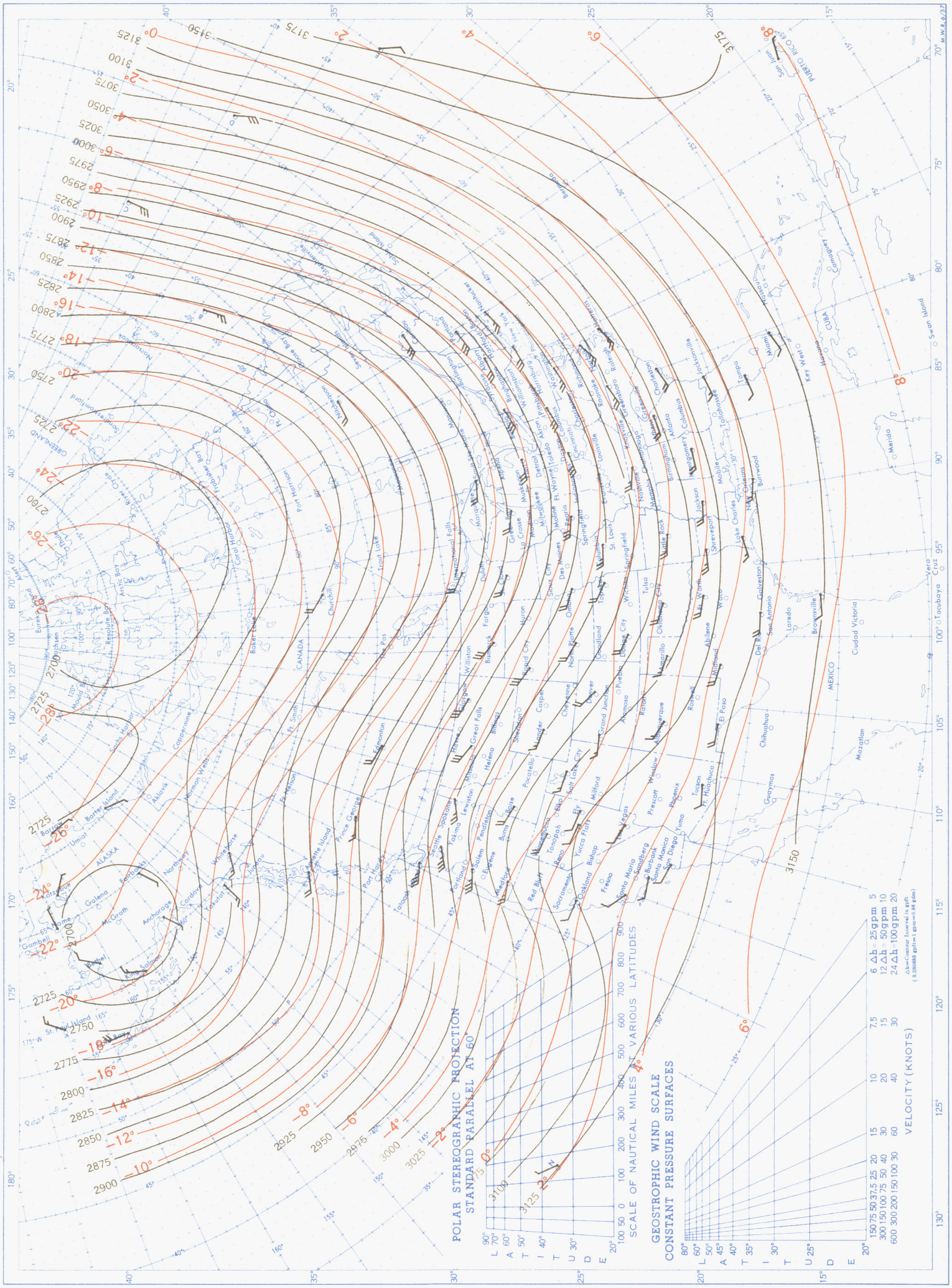
Average sea level pressures are obtained from the averages of the 7:00 a. m. and 7:00 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid based on readings from the Historical Weather Maps (1899-1939) for the 20 years of most complete data coverage prior to 1940.

Chart XII. 850-mb. Surface, 1200 GMT, December 1957. Average Height and Temperature, and Resultant Winds.



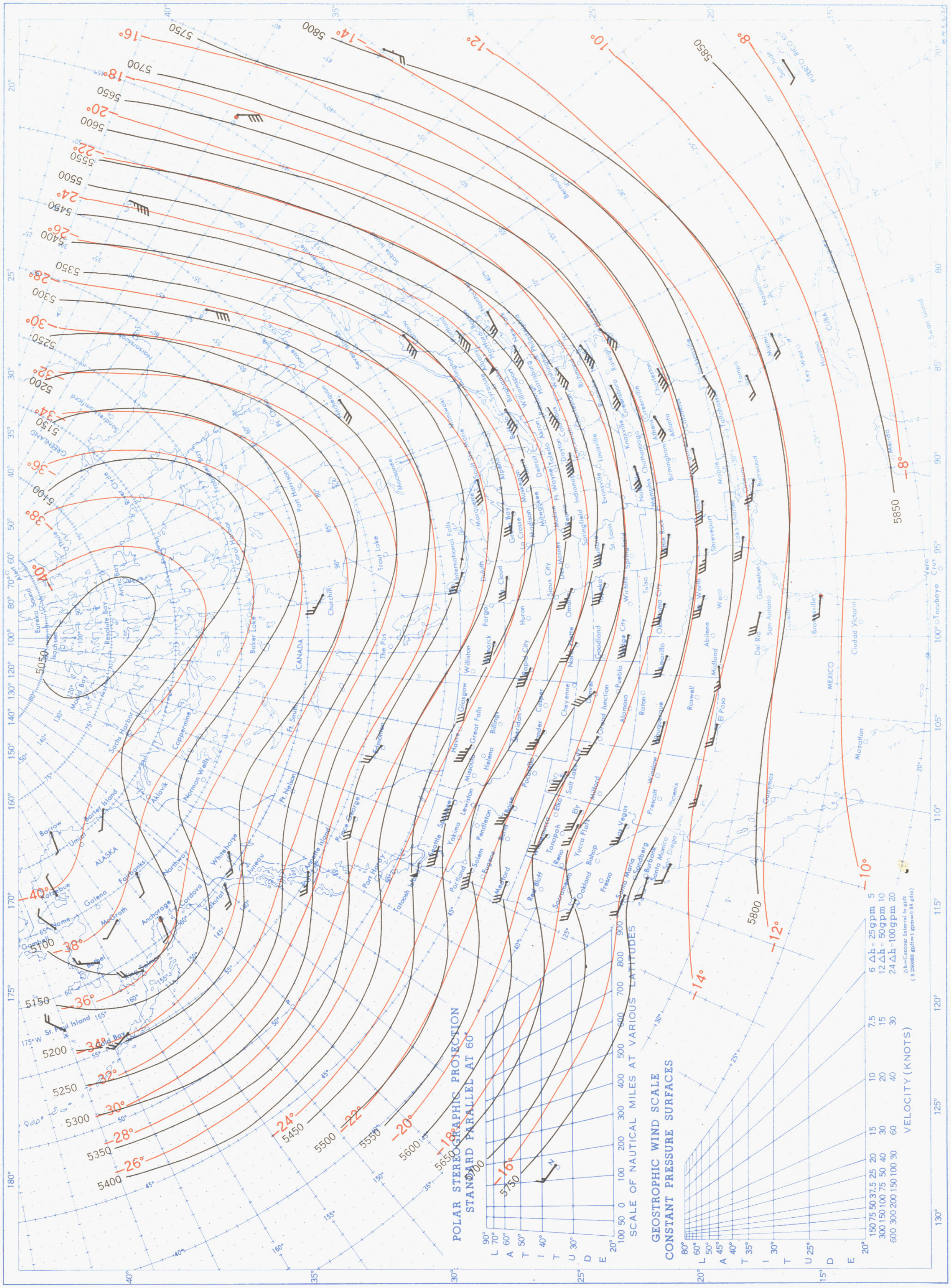
Height in geopotential meters (1 g.p.m. = 0.98 dynamic meters). Temperature in °C. Wind speed in knots; flag represents 50 knots, full feather 10 knots, and half feather 5 knots. All wind data are based on rawin observations.

Chart XIII. 700-mb. Surface, 1200 GMT, December 1957. Average Height and Temperature, and Resultant Winds.



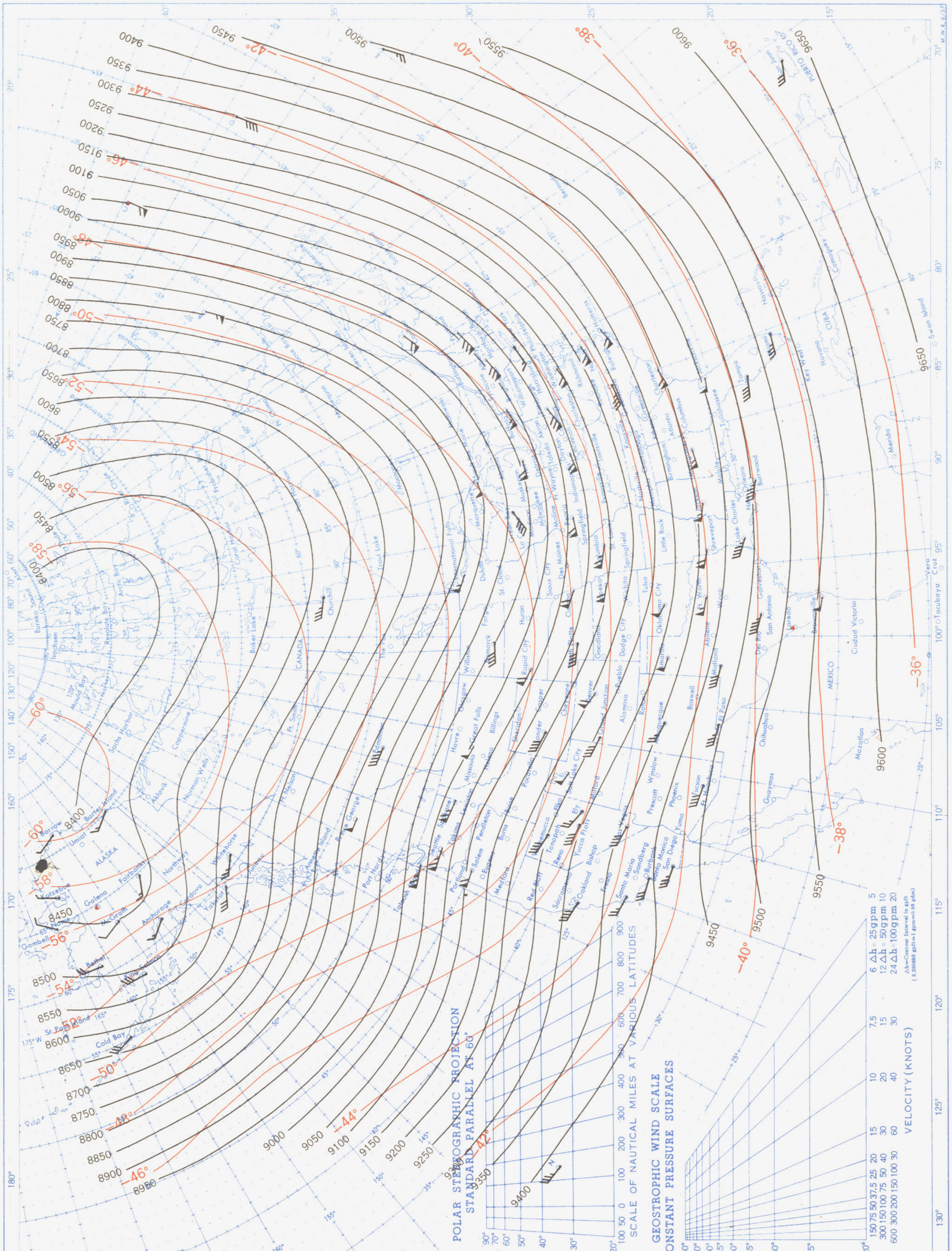
See Chart XII for explanation of map.

Chart XIV. 500-mb. Surface, 1200 GMT, December 1957. Average Height and Temperature, and Resultant Winds.



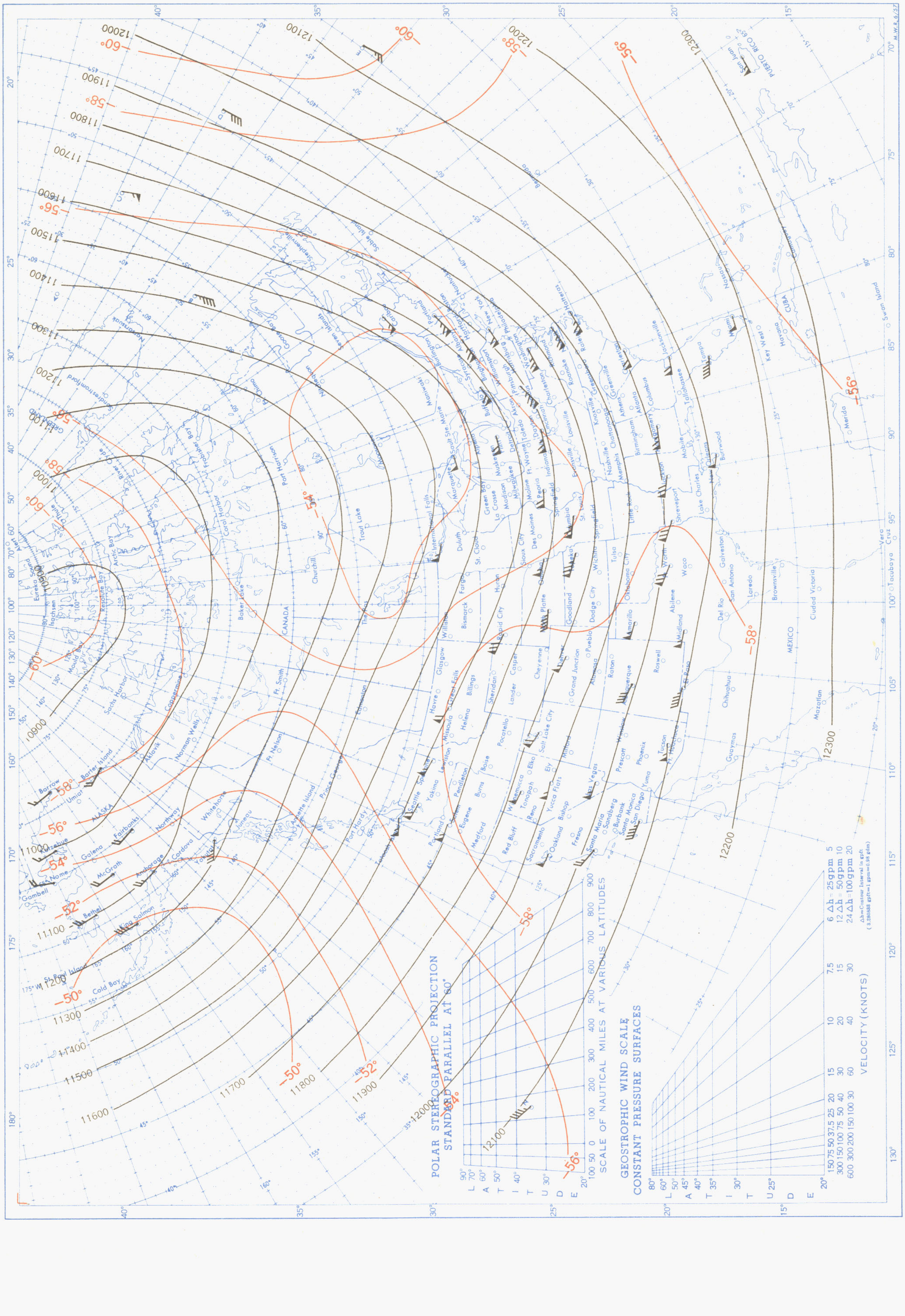
See Chart XII for explanation of map.

Chart XV. 300-mb. Surface, 1200 GMT, December 1957. Average Height and Temperature, and Resultant Winds.



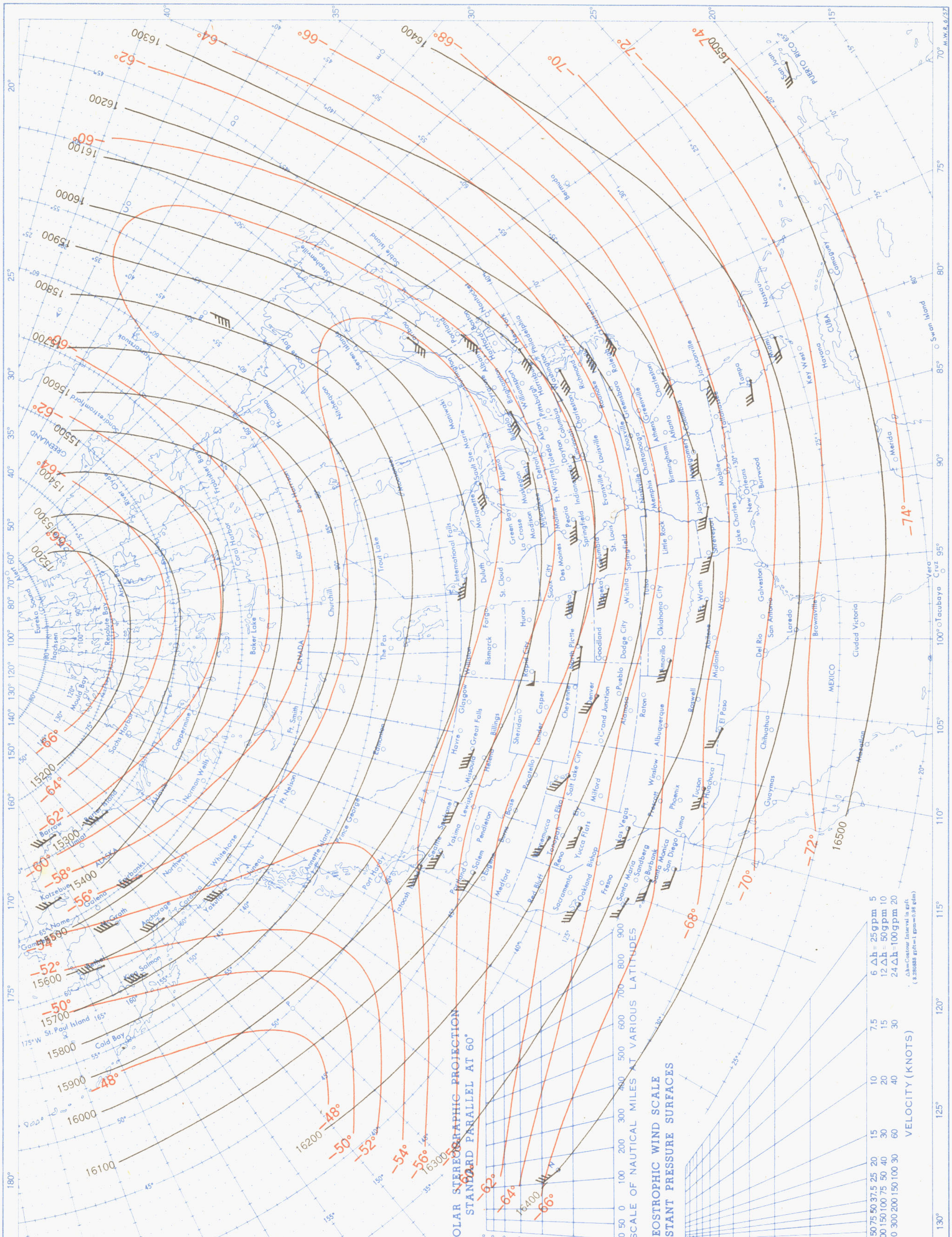
See Chart XII for explanation of map.

Chart XVI. 200-mb. Surface, 1200 GMT, December 1957. Average Height and Temperature, and Resultant Winds.



See Chart XII for explanation of map.

Chart XVII. 100-mb. Surface, 1200 GMT, December 1957. Average Height and Temperature, and Resultant Winds.



See Chart XII for explanation of map.